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GENERAL ELECTRIC REVIEW

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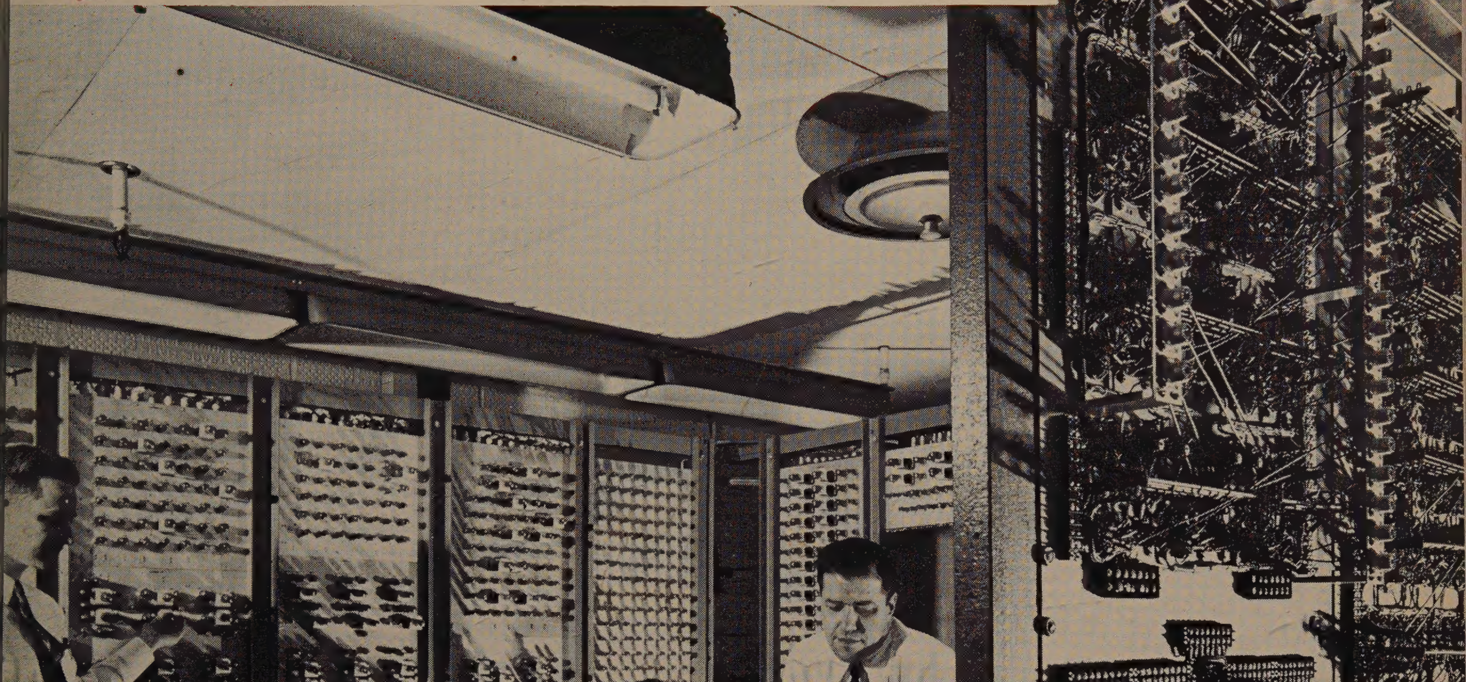

April 1950

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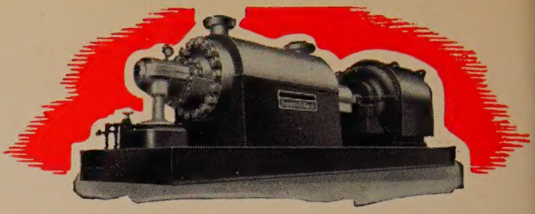

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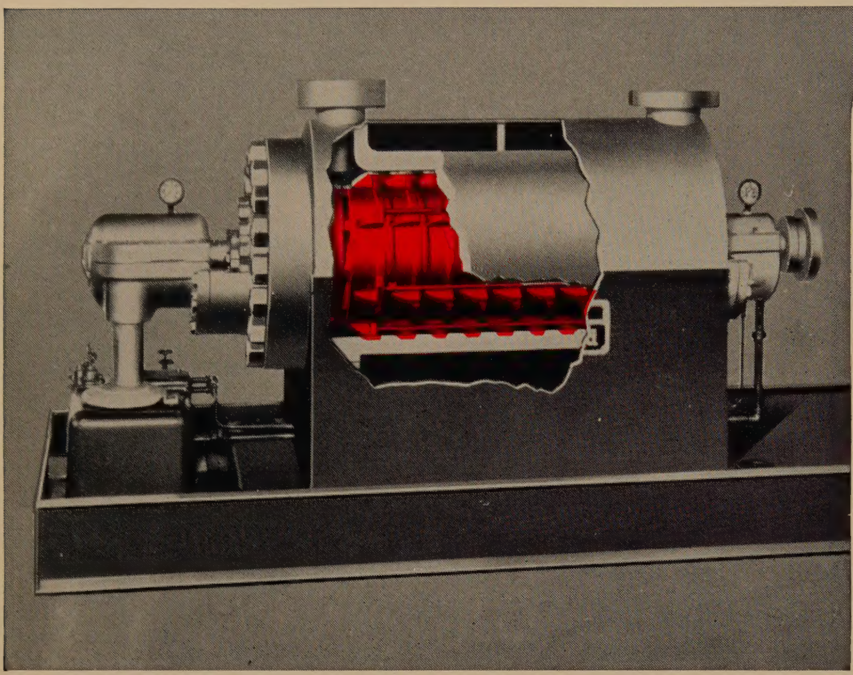

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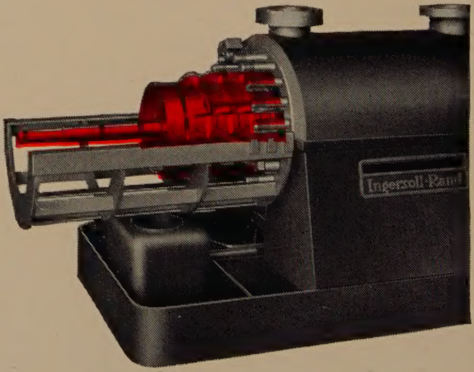

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GENERAL ELECTRIC Review

APRIL 1950
Vol. 53, No. 4

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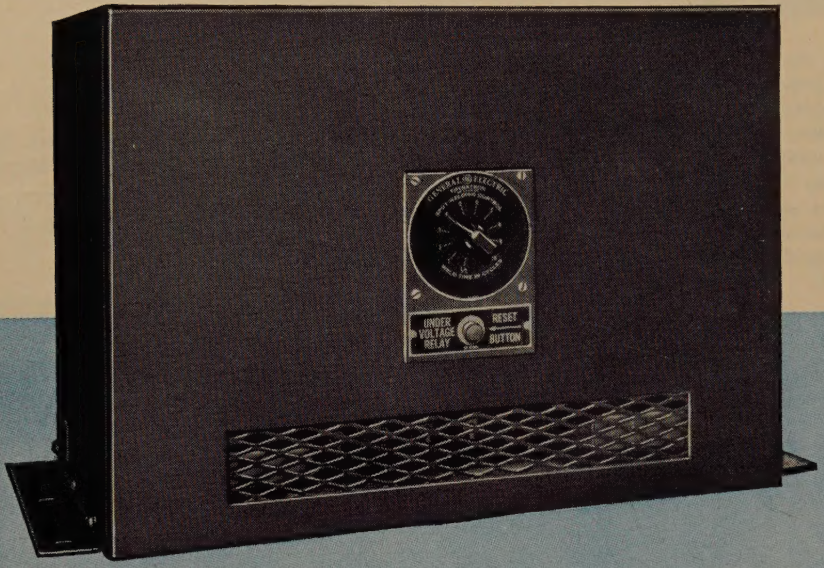

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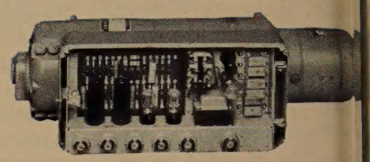

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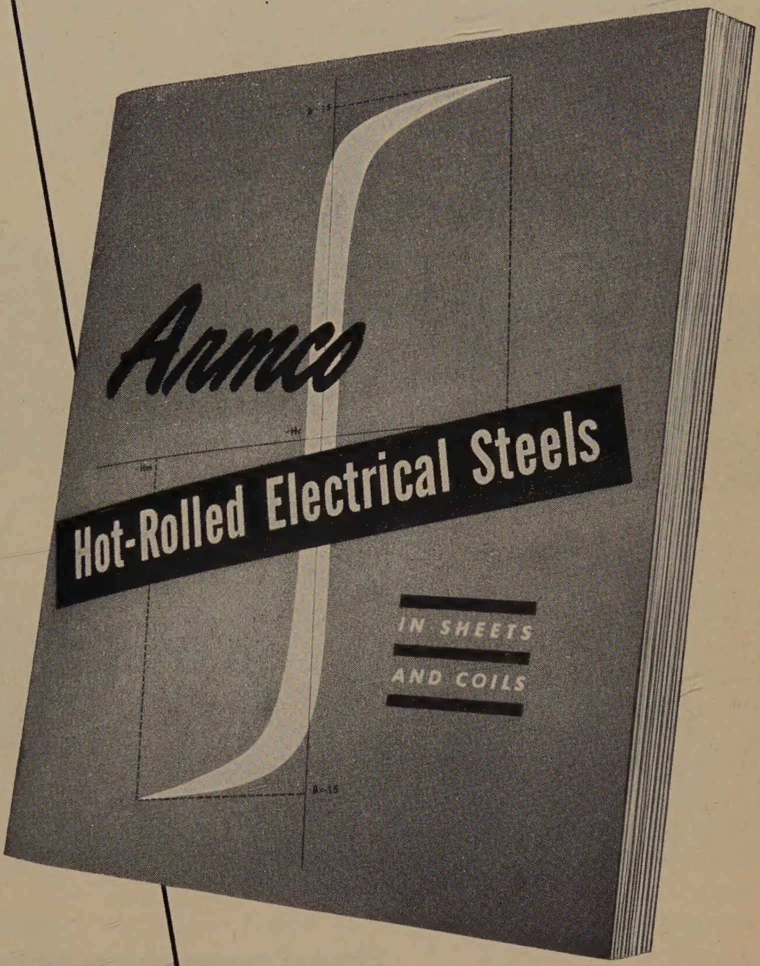

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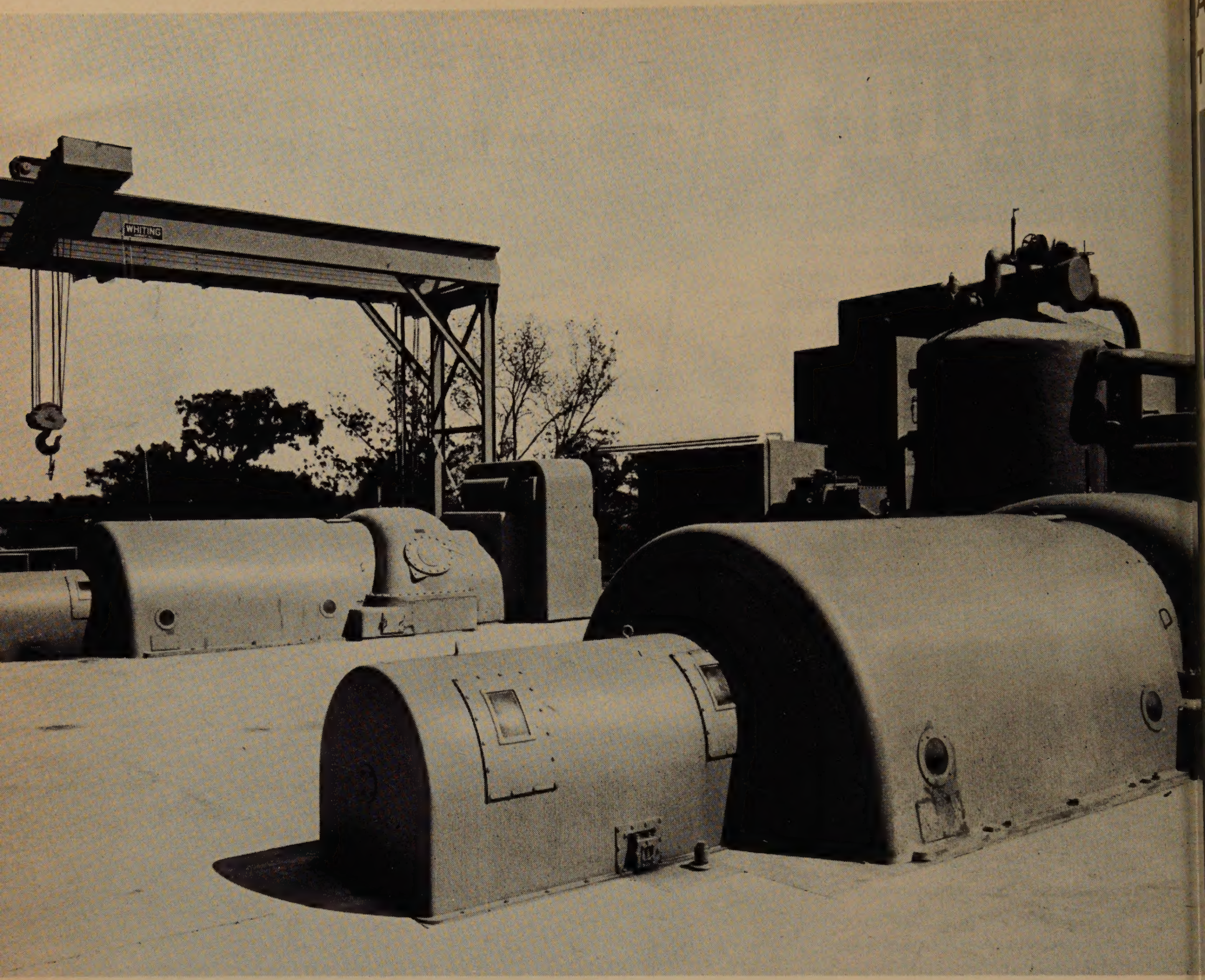
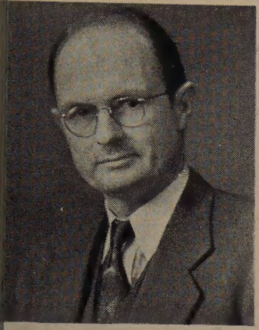


STEAM-TURBINE-GENERATORS: OUTDOOR

Each with its own protective covering, these generating units at a southern power statio operate under conditions so unconventional as to suggest how unusual are the variation successfully met by designers and users of electric-power generating units. (*See page 22*

APPLICATION OF INTERRUPTER SWITCHES TO LOAD-CENTER UNIT SUBSTATIONS . . Part I



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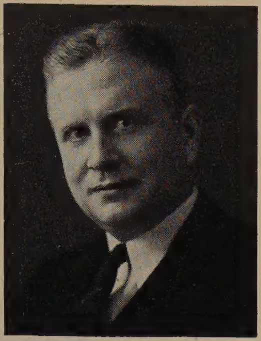

Donald E. Craig

E. M. Hunter

By D. L. BEEMAN
Industrial Power Divisions

D. E. CRAIG*
Unit Equipment Divisions

E. M. HUNTER
Central Station Engineering Divisions
General Electric Company

THE load-center unit substation is being almost universally used in industrial plant power distribution because of its flexibility, safety, and low cost. Although the application of this type of equipment is well understood by most power-system engineers, there still remains at least one important part of these substations about which there is some confusion; that part s the incoming line "interrupter switch" with or without fuses. This article relates to the various types of nterrupter switches available and their intended functions, and clarifies their specific applications.

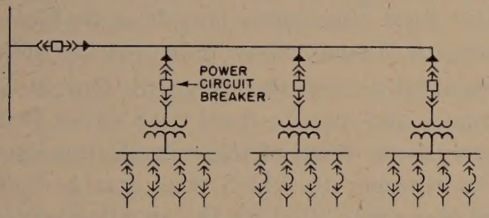

Fig. 1. Ideal load-center distribution system (from safety standpoint)

It is well known that most system engineers consider the use of interrupter switches in unit substations as a partial compromise between an ideal solution from the safety standpoint and a practical solution from the economic point of view. The ideal solution would be to have a power circuit breaker as the incoming-line nterrupting device in each unit substation, as illustrated in FIG. 1. This is, of course, relatively expensive and has resulted in the use of incoming line interrupter switches, as shown in FIG. 2, as the practical compromise system in thousands of industrial plants.

The National Electric Code, 1947 edition, Paragraph 4512b, recognized this situation as follows:

> "A transformer having an overcurrent device in the secondary connection, rated or set at not more than 250 percent of the rated secondary current of the transformer, or a transformer equipped with a co-ordinated thermal overload protection by the manufacturer, is not required to have an individual overcurrent device in the primary connection provided the primary feeder overcurrent device is rated or set to open at a current value not more than six times the rated current of the transformer for transformers having not more than six percent impedance, and not more than four times rated current of the transformers having more than six but not more than ten percent impedance."

From the system layout engineer's point of view, this means that in a system such as that shown in FIG. 2 about four unit substations of *equal* kva rating can be connected to a given feeder with adequate over-all short-circuit protection. If the units *are not* the same size, the "rule of four" can be applied to find out whether the smaller units need individual short-circuit protection. This means that the smallest unit substation that can be applied without its own individual incoming line power circuit breaker or fuses should not be less than one-fourth the total load on the feeder. If the size of one of the unit substations is less than one-fourth the total full load of the feeder, as indicated in FIG. 3, then an interrupter switch and

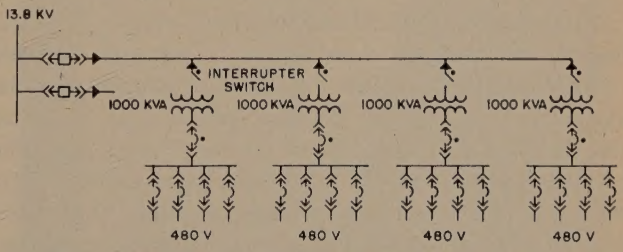

Fig. 2. Standard radial load-center distribution system in common use

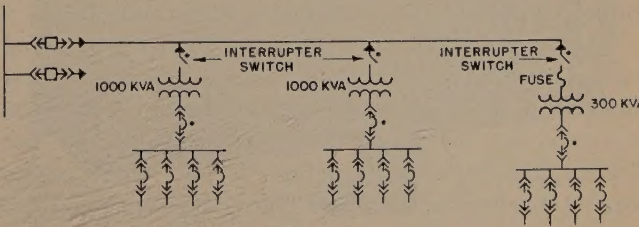

Fig. 3. Load-center system feeder serving both large and small unit substations

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*Now Assistant Manager of Sales, Meter and Instrument Divisions, General Electric Company.

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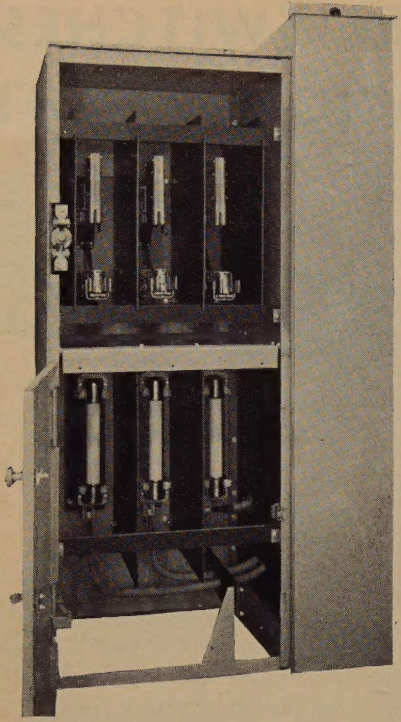


Fig. 4
Interrupter switch
and fuse combination

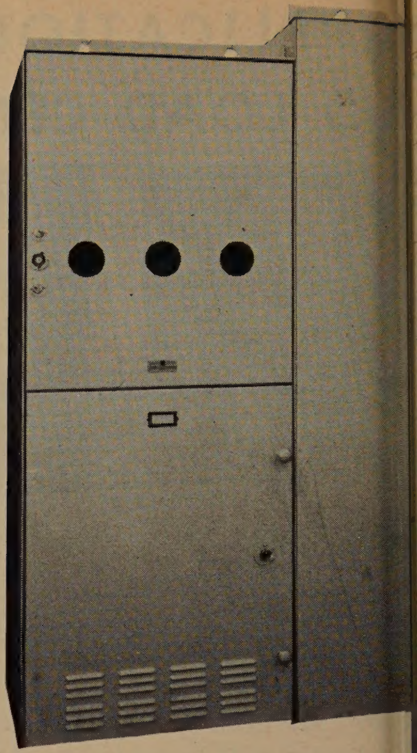


Fig. 5
Air-interrupter switch

fuse combination should be used on this smaller unit to provide short-circuit protection for that unit. The simple interrupter switch without the complication and expense of fuses is adequate for the other units on the same feeder, providing the rating of each is over one-fourth the total feeder load. Fig. 4 illustrates an interrupter switch and fuse combination.

CLASSES OF INTERRUPTER SWITCHES

The term "interrupter switch" is defined in the Power Switching Equipment Standards of NEMA, Paragraph SG50-658, as follows:

> "An interrupter switch is a switch combining the functions of a disconnecting switch and a circuit interrupter for interrupting, at rated voltage, currents not exceeding the continuous current rating of the switch."

By this definition both the so-called "mag-i" and "load break" switches are classified as interrupter switches.

There are three general classes of interrupter switches available today for use on unit substations. These are the air-filled and liquid-filled (Pyranol or oil) switches and the oil cutout. The particular type used is determined by the type of insulation, the kva, and the incoming voltage of the transformer section of the unit substation. Table I lists the specific standard interrupter switch for each of these combinations.

The air interrupter switch (Fig. 5) has several advantages: First, a visible air break is provided so that there is no question as to whether the unit substation is or is not definitely disconnected from the line. Second, the insulating medium is air, which cannot leak or require maintenance. Third, the switch contacts are readily accessible for testing or phasing-out the transformer and cable circuit. Fourth, there is no liquid to volatilize, thus reducing the possibility of a pressure burst if the switch is operated beyond its ability. The disadvantage of the air interrupter switch is that, since all the necessary electrical clearances are in air, it is necessarily somewhat larger than a liquid-filled switch. The larger floor dimensions may be a problem if only the minimum of space is available for the substation.

The liquid-filled switch, shown in Fig. 6, is small and compact and may be filled with either Pyranol or oil depending on which of these insulating oils is used in the transformer to which it is attached. The advantages previously cited for the air-filled switches will be found as limitations in the liquid-filled switches. In

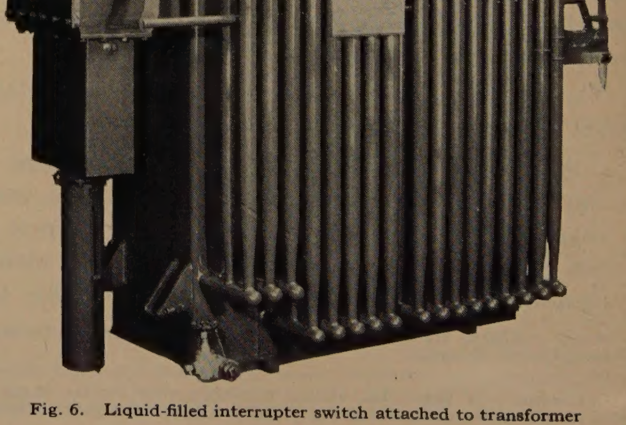


Fig. 6. Liquid-filled interrupter switch attached to transformer

TABLE I: INTERRUPTER SWITCH APPLICATION

Transformer Section Kva	Transformer Section Type		
	Pyranol	Dry	Oil*
	INCOMING CIRCUIT—2400 VOLTS		
100– 750 incl.	Oil Cutout (Fig. 7)	Oil Cutout (Fig. 7)	Oil Cutout (Fig. 7)
1000–2000 incl.	Air Switch (Fig. 5)	Air Switch (Fig. 5)	Oil Switch (Fig. 6)
	INCOMING CIRCUIT—4160–4800 VOLTS		
100–1000 incl.	Oil Cutout (Fig. 7)	Oil Cutout (Fig. 7)	Oil Cutout (Fig. 7)
1500–2000 incl.	Air Switch (Fig. 5)	Air Switch (Fig. 5)	Oil Switch (Fig. 6)
	INCOMING CIRCUIT—5001–15,000 VOLTS		
100– 500 incl.	Pyranol Switch (Fig. 6)	Air Switch (Fig. 5)	Oil Switch (Fig. 6)
750–2000 incl.	Air Switch (Fig. 5)	Air Switch (Fig. 5)	Oil Switch (Fig. 6)

*Oil-insulated transformers normally used in outdoor applications.

ddition, after several hundred operations, the insulat-ng liquid must be filtered to remove the products of rcing which are mostly carbon. The liquid-filled witches are suitable for interrupting only the magne-izing currents of the transformers with which they are isted in Table I. They are furnished with remote oper-ting handles as shown in Fig. 6 so that the operator as the transformer between him and the switch. The il cutout (Fig. 7) is a very sturdy device, takes little pace and is well adapted to use with either liquid or ry-type transformers. The question of the oil in the utout when used with a dry-type transformer presents o practical problem because of the very limited amount f oil involved (approximately two quarts per cutout). his is recognized by the National Electrical Code, rticle 710, Section 7143, which allows the use of these utouts without being installed in a fireproof vault.

LOAD-BREAK'' VS ''INTERLOCKED'' INTERRUPTER WITCHES

Considerable confusion has surrounded the term load break'' switch. For unit-substation applications, here does not seem to be any practical requirement or making an interrupter switch actually operate under ny more severe duty than the magnetizing current of he transformer. As a matter of fact, there are very ood reasons for interlocking switches, regardless of heir interrupting ability, so that only transformer nagnetizing current is interrupted. It is very simple o safely key-interlock the interrupter switch with the nain low-voltage secondary breaker so that this breaker nust be open (and therefore all load dropped) before he opening or closing of the interrupter switch. As nentioned earlier, the use of the interrupter switch on nit substations is at best a compromise and, even hen constructed as well as possible, it does not have uilt-in overload or short-circuit protection; therefore, t is still by far the weakest part of the unit substation. hese facts develop two basic reasons for key-inter-ocking interrupter switches: (1) *safety to personnel* and 2) *protection to service continuity*.

The safety-to-personnel problem can be discussed at reat length but the proof of the pudding can be found n the published accident reports. For example, the 1947 EEI accident report lists four deaths during the year from misoperation of disconnecting switches in the voltage classes 15 kv and below. The ones listed were only those in the electric utility field and did not include industrial plants, where the operators do not have occasion to be as experienced as in the electric utility field. This indicates definitely that disconnecting-switch operation is a hazardous and serious problem which merits the utmost consideration in industrial system application engineering.

Since most misoperations of interrupter switches can be prevented by means of key interlocking, safety to personnel would seem to demand that the switches be interlocked.

Assurance of greater *continuity to service* is also provided by key interlocking. Most plant operators are familiar with the annealing of switch contacts that often

(Continued on next page)

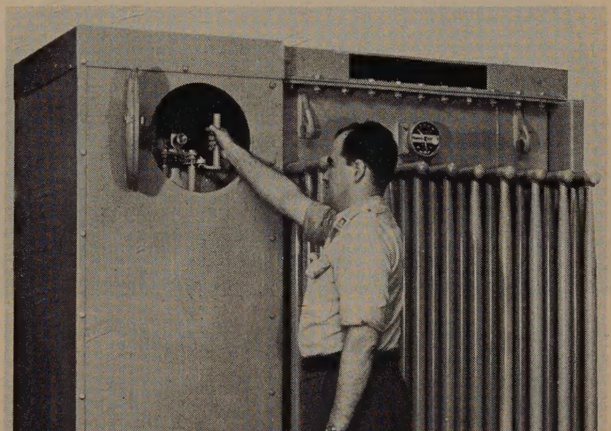
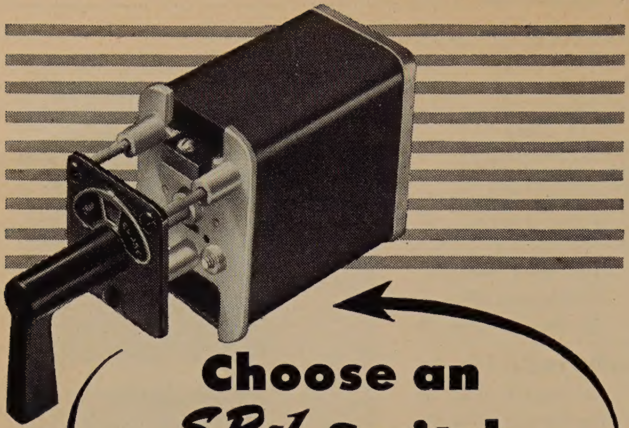


Fig. 7. Oil-cutout interrupter switch in use on Pyranol transformer



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INTERRUPTER SWITCHES

(Continued from preceding page)

occurs from overloading knife switches or from operating this kind of device when not fully closed. Annealed contacts mean shutting down not only the particular unit substation involved but also the feeder serving it and all other units on that feeder. Key interlocking effectively prevents a careless operator's leaving any interrupter switch partially closed, because the key cannot be removed from the interlock on the switch until it is closed properly. Thus entire feeder shutdowns from this cause are prevented by the key interlocking of interrupter switches.

Possibility of misoperation or attempting to operate interrupter switches beyond their current handling ability is greater when no interlocks are provided. For example, suppose a substation is de-energized with a large motor or several small motors connected to the low-voltage bus. Should the substation be re-energized by closing the noninterlocked interrupter switch, the switch must close on the full starting current of the motors, which current probably will be several times full load current and beyond the ability of the switch.

Another case may be where there has been maintenance work done of the low voltage switchgear bus and a wrench has been left on the buses. When the noninterlocked switch is closed it is closed on a secondary bus fault, a duty which is beyond the ability of most interrupter switches.

These are merely two possible examples which indicate how omission of the interlocks may enable the interrupter switch to be closed in on current in excess of its rating.

This condition is further aggravated when the operator closes the switch only part way or just "kisses" the contacts. He will usually attempt to open the switch and try again. When the switch is opened after partial closure it may arc over at currents even less than interrupting rating, depending upon how far the switch was closed on the first try and how fast and far it was opened for the second try. With an interlocked switch, only transformer exciting current is handled under any of the foregoing conditions. Any short circuits or excessive load currents on the secondary are handled by the main or secondary circuit breakers.

It should be pointed out, however, that the fullest benefits of interlocking are obtained when a main secondary circuit breaker is provided. Not only is interlocking simpler but, in the event of faults on the secondary bus, the fault is handled by an adequate circuit breaker and not the primary disconnecting switches.

As may be reasoned from these comments, the ability of an interrupter switch to perform within its interrupting rating is not questioned. It is applied to a circuit which can produce currents beyond its interrupting rating. The hazards from these excessive currents can be kept to the minimum by interlocking which permits the switch to interrupt only transformer magnetizing current. Often the system can be so arranged that the interrupter switch can be operated de-energized ıd this should be done whenever possible. The inter- ıpting element on the switch is then only an added ıfety device which affords some additional protection) the operator if he makes a mistake.

It is well to point out here that whether or not the vitches are interlocked they may be closed on a fault ı a transformer. However, such faults are so rare that ıe chance of failure from this cause is very remote ɔmpared with other possibilities of faulty operation of ninterlocked switches as mentioned above. This con- ngency can be avoided only by the use of a power ırcuit breaker in place of the interrupter switch.

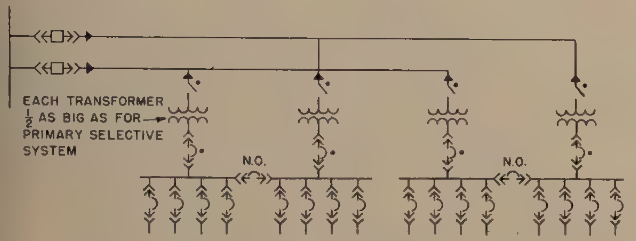

Fig. 8. Secondary selective load-center system

Therefore, since it is usually very simple to interlock he interrupter switch, obtain maximum safety and ontinuity of service, and still not lose any flexibility f operation, it would seem logical to provide this eature always, regardless of whether the interrupter witch or so-called "load break" switch has the ability o break full load current of the substation. This will liminate the most likely cases under which the switch an be misoperated or operated beyond its ability.

WITCHING FUNCTIONS

Interrupter switches have been used on unit sub- tations to provide three different functional kinds of ervice. By far the most common is to provide simple solation of the unit substation from its incoming eeder, as indicated in Fig. 2. Here the maximum in- ended duty of the switch is to disconnect the trans- ɔrmer from the energized incoming line, breaking only he magnetizing current of the transformer. This is a easonably safe operation, providing the interrupter witch is key-interlocked to prevent making or break- ıg high currents caused by such mishaps as low-voltage eeder circuit breaker failing to clear secondary short ircuit or excessively high inrush current from a group f large motors.

For the straight radial system (Fig. 2) or secondary elective system (Fig. 8) this simple isolating function f the interrupting switch is all that is required. It hould be pointed out, however, that in re-energizing transformer the safest procedure is to operate the witch with the primary feeder de-energized. Other- vise, should something have happened in the trans- ɔrmer to cause a fault, the switch would be subjected) closing in an energized primary feeder on a fault. ı the secondary selective system it is easy to drop ıe feeder long enough to close the switch, because ıe load can be transferred to another bus during the witching period.

(To be continued)

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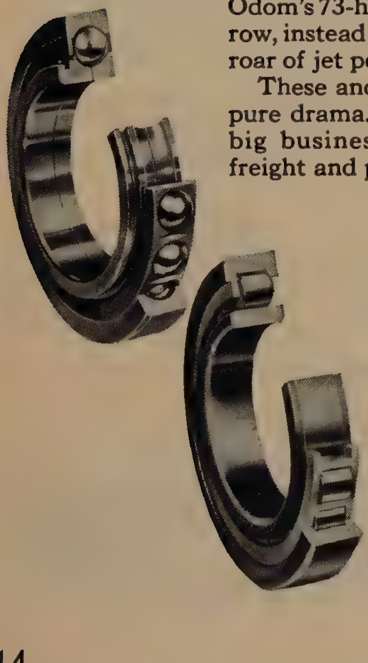

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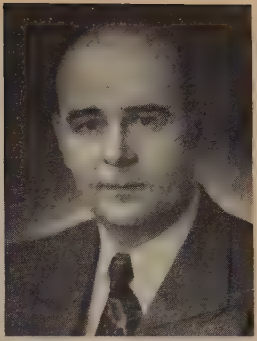
HIGH-VOLTAGE HIGH-INTERRUPTING-CAPACITY A-C MOTOR CONTROLLERS

Growth in capacity of power-supply systems has resulted in development of motor controllers capable of interrupting the huge amount of power a modern power system could send into a faulted motor circuit



GW Heumann

By G. W. HEUMANN
Control Engineering Divisions, Apparatus Department
General Electric Company

UNDER the Industrial Control Standards of the National Electrical Manufacturers' Association (NEMA), which are widely accepted by users as well as manufacturers of control apparatus, standard magnetic a-c contactors have an interrupting capacity of ten times their continuous motor-current rating. High-voltage and low-voltage controllers utilizing such contactors are designated as "Class A" controllers. The ten-times-normal interrupting rating is entirely adequate to take care of any operating overloads which may be imposed on the current-carrying parts of the controller, the worst being that encountered when the controller has to interrupt the stalled-rotor current of the motor.

OVERLOAD VERSUS FAULT PROTECTION

Operating overloads are determined by motor size, and protection against them is provided by suitable overload relays that are generally of the thermal type. The maximum current (stalled-rotor current) which may be drawn by a given motor is a multiple of the normal rated motor current, the multiplication factor varying somewhat with the motor type. Rarely, however, does the maximum operating overload exceed ten times normal current.

In addition to protecting the motor against damage due to excessive current, the controller should protect itself—and also the branch-circuit conductors between the controller and the motor—against damage due to short circuits. The magnitude of the short-circuit current due to a fault at any point in a power system has nothing to do with the size of the motor which happens to be connected at that point in the system. The short-circuit current is governed solely by the characteristics of the power system. The magnitude of that current equals the generator emf divided by the total impedance of the generator, the transformers, and the transmission and distribution lines between generator and fault. Hence, the motor size has no influence on the fault current which a controller may be called upon to interrupt.

When industrial power systems were small and many users generated their own power, isolated from any interconnected system, Class A controllers were considered entirely adequate. Motor overload protection was taken care of by the contactors. Short circuits were cleared by substation breakers, and the thermal capacity of the controllers was sufficient to carry the moderate short-circuit currents for the time interval required for the substation breakers to clear the fault. FIG. 1 shows a typical high-voltage controller of a type that was built some 30 to 40 years ago, and which established an excellent service record in those days.

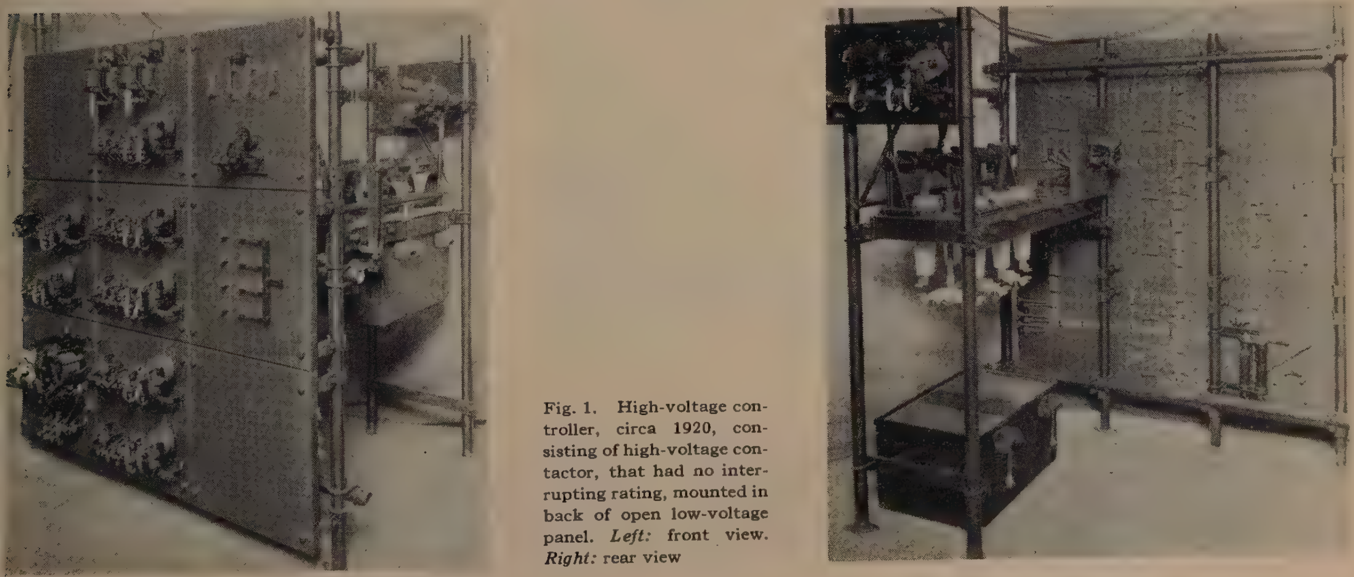


Fig. 1. High-voltage controller, circa 1920, consisting of high-voltage contactor, that had no interrupting rating, mounted in back of open low-voltage panel. *Left:* front view. *Right:* rear view

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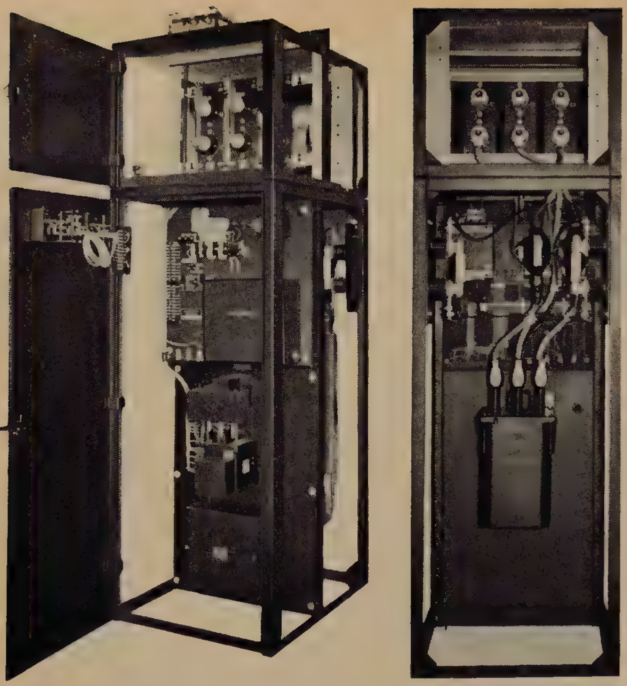

Fig. 2. Class E1 high-voltage high-interrupting-capacity controller with an oil circuit breaker as the current interrupting means. *Left:* front view. *Right:* rear view

Today, the small and isolated power systems are largely a thing of the past. Industrial power systems now form part of, or are tied in with, large interconnected public utility systems. At 2300 and 4000 volts, which are the most commonly used high voltages, short-circuit values as high as 150,000 to 250,000 kva are frequently encountered.

CLASS E CONTROLLERS

A casual examination of Fig. 1 indicates that a contactor, which was entirely adequate in the days of small and isolated power systems, could not possibly handle the high short-circuit currents encountered in present-day industrial power systems. Recognizing this situation, NEMA has established "Class E" for controllers which are capable of interrupting power under short-circuit conditions. In other words, Class E controllers have a high interrupting rating, in addition to their conventional motor rating.

Two types of those controllers are recognized. Class E1 controllers employ the contacts of the controller for both starting the motor and interrupting short circuits. Such controllers include special contactors or circuit breakers designed to interrupt their rated short-circuit capacity. Standard ratings are 25,000 and 50,000 kva. Controllers of this type require several cycles for clearing the fault, and the apparatus must be designed to withstand the mechanical and thermal stresses imposed by the short-circuit current.

A typical Class E1 controller is shown in Fig. 2. An oil circuit breaker is utilized for handling the motor-power circuit. Low-voltage control circuits are connected to a control transformer, the primary side of which is protected against faults by high-voltage fuses.

Class E2 controllers employ the contacts of the controller for starting the motor and fuses for interrupting the short-circuit current. Since the contacts do not have to interrupt any higher currents than those corresponding to motor stalled-rotor current, standard Class A contactors can be used on such controllers. The interrupting rating of the controller is determined by the interrupting rating of the fuses. Standard ratings are 150,000 kva at 2300 volts, and 250,000 kva at 4000 volts.

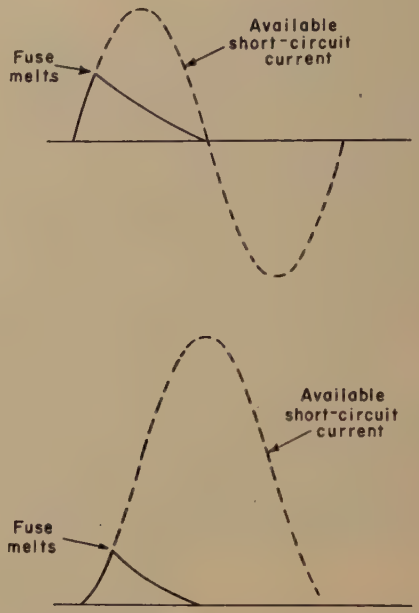

Fig. 3. Curves showing the current-limiting action of current-limiting fuses. *Above:* with symmetrical short-circuit current. *Below:* with asymmetrical short-circuit current

The thermal capacity of the controller must be such that it can carry the short-circuit current during the time interval required by the fuse to clear the fault. So-called power fuses permit the full short-circuit current to flow for one or two cycles, after which current interruption takes place. Current-limiting fuses are fast-acting fuses consisting, for instance, of a silver wire embedded in quartz sand which interrupts the short-circuit current during its initial rise in the first half-cycle. Therefore, the current is interrupted before it has reached the first peak of the available short-circuit current.

This current-limiting action is illustrated in Fig. 3. The dashed curves represent the available short-circuit current for both the symmetrical and the asymmetrical conditions. The solid curves are the currents actually flowing in the controller. Current-limiting action of the fuses thus reduces the current, and consequently the mechanical and thermal stresses imposed on the controller which, except for the fuses, may be of Class A construction. To protect against possible faults in the control circuit, current-limiting fuses are provided on the high-voltage side of the control transformer.

Fig. 4 shows typical views of Class E2 controllers. The central illustration shows the current-limiting ower fuses which are mounted in a compartment at he top of the controller. The front door, through which he fuses are accessible, is equipped with a door interock that causes the line contactor to be tripped when he door is opened, so that the motor is disconnected efore the fuses can be pulled. Barriers separate the uses. The fuse fittings are so arranged that the fuses erve as switch-hook-operated disconnect switches. he fuses themselves must have sufficiently high curent-carrying ability so that they will not interrupt on tarting current peaks and operating overloads. Their using conductor must be sufficiently small that interuption will take place during the initial current rise f the first half-cycle of the short circuit. No general ode has been established to govern the application of urrent-limiting fuses to specific motor applications. The manufacturers' recommendations should be folowed in selecting the proper fuse size for a given motor ontroller.

The compartments housing the high-voltage power equipment and the low-voltage control equipment are separated by metal partitions, thereby enhancing the safety of the operator by reducing the hazard of his coming in accidental contact with high-voltage parts when making adjustments to relays or the like on the low-voltage devices. Buses and primary wiring are so selected and braced that they can withstand the stresses imposed by the short-circuit currents. The primaries of the instrument and control potential transformers are protected by current-limiting fuses to prevent these devices, being damaged by faults in the high-voltage control or metering circuits. Thus the design of the whole controller assembly is properly co-ordinated to withstand any electrical and mechanical stresses caused by short-circuit currents within the controller rating.

The choice between Class E1 and Class E2 controllers is governed by available short-circuit capacity at the point of installation, and by economic considerations. Up to 50,000 kva interrupting rating, both Class E1 and E2 controllers can be used, and the choice may be governed by the cost of the equipment for a given motor application. A limitation to the use of Class E2 controllers is the largest-size current-limiting fuse available. The largest size of induction motors for which Class E2 controllers are available is 700 hp at 2300 volts and 1250 hp at 4000 volts. For larger motor sizes, only Class E1 controllers are suitable.

OIL-IMMERSED AND AIR-BREAK CONTACTORS

Class E2 controllers can be obtained either with oil-immersed or with air-break contactors. For the oil-immersed contactor, all arcing parts are enclosed in an oil tank, and they are below the oil level. The contacts are not equipped with blowouts and arc chutes, and the oil is relied upon to quench the power arcs. Since oil has high insulating properties, minimum spacing is sufficient between current-carrying parts of opposite polarity. Hence, controllers utilizing oil-immersed contactors can be built to the smallest dimensions for a given rating. Since the contacts are located under oil, they are protected against attack by corrosive atmospheres, which means that oil-immersed equipment may be installed in locations unsuitable for air-break controllers.

Two features, which are basic and independent of any specific design, must be considered when selecting oil-immersed contactors. One is the oil tank, which requires a certain amount of maintenance. Any insulating oil will carbonize and sludge in time, for which reason the contactor parts must be cleaned and the oil

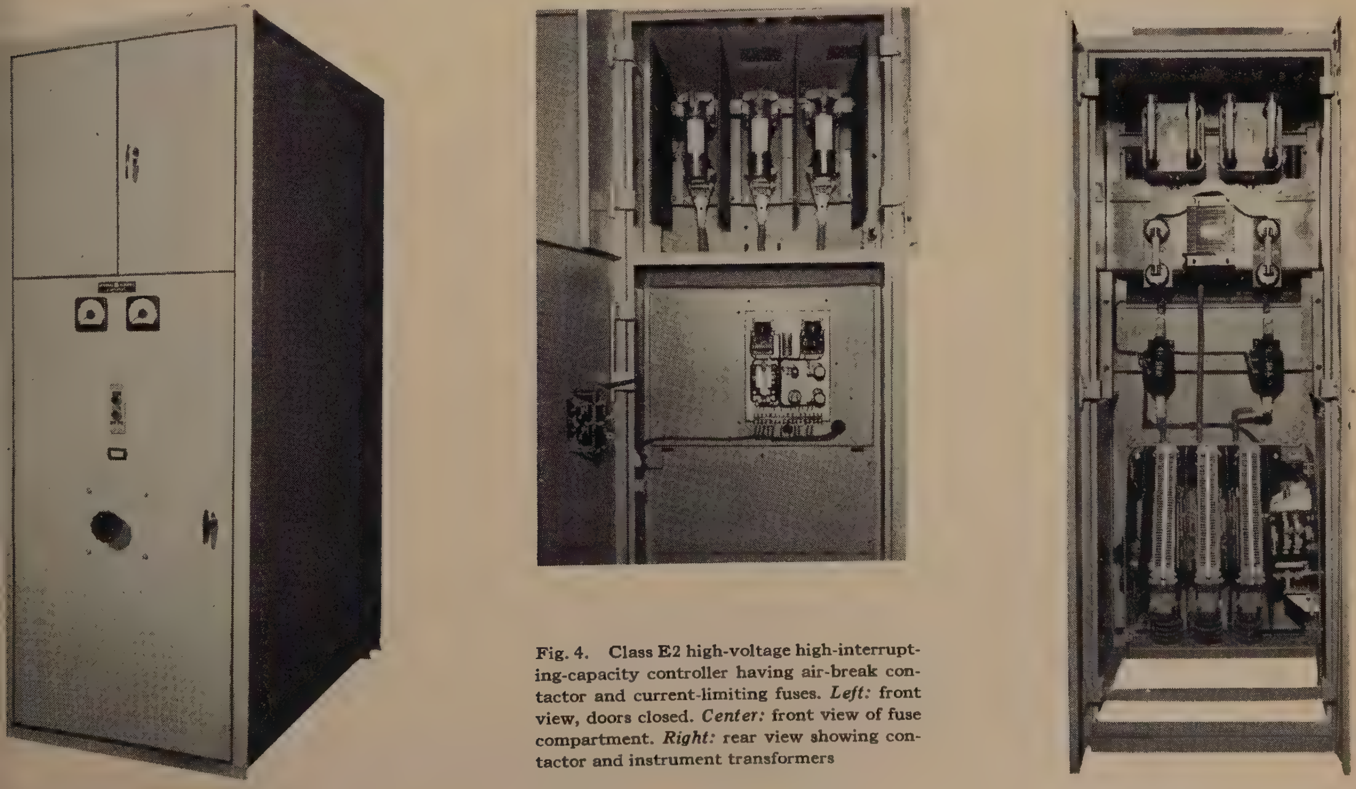

Fig. 4. Class E2 high-voltage high-interrupting-capacity controller having air-break contactor and current-limiting fuses. *Left:* front view, doors closed. *Center:* front view of fuse compartment. *Right:* rear view showing contactor and instrument transformers

renewed at regular intervals, depending on the severity of the service. Good maintenance is imperative; leaky oil tanks constitute a fire hazard. Another consideration is contact life. Experience has revealed that contacts arcing under oil have a shorter life than contacts arcing in air. Therefore, oil-immersed contactors should not be used in controllers which start and stop the motor frequently.

Air-break contactors must be equipped with blowouts and arc chutes. When these contactors are used in corrosive atmospheres, they do not have the advantage of the oil-immersed type. However, possible fire hazard due to the presence of oil is eliminated, maintenance is simplified, and contact life is increased. Air-break contactors should be specified when the controller will be used for frequent starting and stopping of the motor, especially when it is expected that a considerable amount of jogging will be needed.

AVAILABLE SHORT-CIRCUIT CAPACITY

In the preceding paragraphs the term "short-circuit current" has been used somewhat glibly. To provide a full understanding of the basis on which high-interrupting-capacity controllers are rated and applied, it appears desirable to explain in more detail the nature of the short-circuit phenomena which must be handled by the controller.

The interrupting duty imposed on the controller is not only a function of the current which has to be interrupted but also of the system voltage. In other words, the interrupting duty is a matter of power, and for this reason the short-circuit duty of high-voltage interrupting devices is generally expressed in terms of short-circuit kva. While the short-circuit current determines the thermal and mechanical stresses on the current-carrying parts, the system recovery voltage after circuit interruption (for practical purposes the nominal system voltage) determines the length of arc duration and consequently the amount of energy which has to be handled by the controller contacts. The kva short-circuit capacity of the system at a given point equals the short-circuit current, multiplied by the nominal system voltage, multiplied by $\sqrt{3}$ for a three-phase system.

Since the short-circuit current (or kva) depends on the total impedance between the power source and the fault, and thus depends on the location of the fault, it is important to make proper assumptions to determine the maximum short-circuit current or kva which the controller may be called upon to interrupt. For this analysis, reference is made to Fig. 5, which is a simplified schematic diagram of a typical industrial power system. At the point of generation, voltage is stepped up to transmission-line level, at which power is brought to the plant. Through a bank of step-down transformers, the voltage level is reduced to motor distribution voltage, say 2400 or 4160 volts. For the sake of simplification, all switching equipment except the motor controller has been omitted. For a calculation of the maximum short-circuit kva which may have to be interrupted by the controller, the following assumptions are in order:

(1). The worst case to be considered would be the incidence of a short circuit at the load terminals of the controller. The controller itself offers a certain impedance to the flow of current. Since this impedance is small, and depends on a number of factors such as motor size (affecting the size of the overload relays), the controller impedance is neglected and the short-circuit kva is calculated as if the short circuit occurred at the line terminals of the controller. This is commonly called the available short-circuit kva of the system.

(2). While the actual current flowing during a fault depends on the impedance of the fault, such impedance is a variable which is difficult to determine. To be on the conservative side, impedance is generally neglected for faults on circuits of 2400 volts and above.

(3). Industrial power is generally taken from a fairly large system, including a multiplicity of interconnected generating stations and transmission lines. It is therefore assumed that, during a short circuit in a motor circuit, voltage is maintained on the high side of the step-down transformers. In other words, it is assumed that the step-down transformer is connected to an infinite bus. This again is a simplification which is on the conservative side since any reduction in voltage on the high side of the step-down transformer would result in a reduction of the short-circuit kva below the calculated value.

When calculating the maximum short-circuit current which the controller may have to interrupt, the only impedances considered are those of the step-down transformer and the motor feeder. Since their impedance consists largely of reactance (resistance being negligible) the short-circuit current is calculated by dividing the nominal system voltage by the reactance between the infinite bus and the fault. It is customary to express the reactance of the transformer and the motor feeder in per-unit values, referred to the rating of the transformer. This reactance value may be obtained by the user from his power company, in case the power company owns the transformer, or from the transformer nameplate if the user owns the transformer. Dividing the transformer rated kva by the transformer plus feeder reactance gives the available short-circuit kva at the point of controller installation. As an example, assume the step-down transformer bank has a rating of 7500 kva; that its per-unit reactance is 0.05; and that the feeder per-unit reactance is 0.01. The available short-circuit capacity is then $7500/0.06 = 125{,}000$ kva. This means that the motor controller should be selected for a standard interrupting rating of 150,000 kva.

The short-circuit current corresponding to the short-circuit kva just calculated is the symmetrical rms hort-circuit current which would flow after a number f cycles, if no interruption took place. A symmetrical hort-circuit current consisting of a pure a-c wave upper wave in Fig. 6) results if the short circuit occurs t the instant the system voltage wave is at its peak. f the short circuit occurs at any other instant, the otal short-circuit current consists of the a-c wave vhich is superposed on (or offset by) a d-c component lower wave in Fig. 6). The magnitude of the d-c component depends on the instant the short-circuit occurs. The maximum d-c component is obtained if the short circuit occurs when the system voltage wave passes through zero. The d-c component is an exponential current which drops to zero after two or three cycles, the time constant being proportional to the ratio of reactance to resistance in the circuit between power source and fault. The actual amount of short-circuit current flowing during a fault would lie somewhere between the extremes illustrated in Fig. 6.

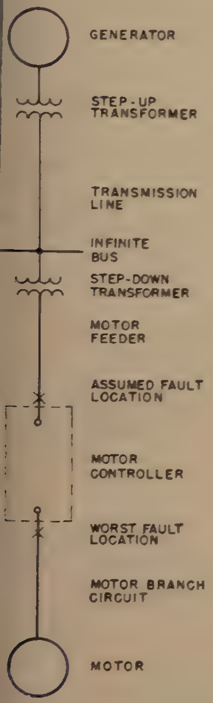

Fig. 5
Schematic diagram of high-voltage power utilization system

BASIS OF CONTROLLER INTERRUPTING RATING

When Class E1 controllers with contactors or circuit breakers, or Class E2 controllers with power fuses, are used for fault interruption, the actual current interrupted is equal to, or larger than, the available symmetrical short-circuit current. Comparatively slow-acting oil circuit breakers, requiring about 8 cycles for current interruption, will have to interrupt only the a-c component of the short-circuit current, since the d-c component has disappeared before the breaker contacts part. Power fuses, which may interrupt after the first half-cycle, would have to be capable of interrupting the a-c component plus the full d-c component of the available short-circuit current.

Circuit breakers and power fuses are generally rated in terms of the maximum rms short-circuit kva they can interrupt. Such ratings can easily be verified by measuring the actual power interrupted during short-circuit tests. When such devices are applied for branch-circuit protection, the maximum rms short-circuit kva to be interrupted would have to be determined, and may be higher than the symmetrical available short-circuit kva as determined by the method of calculation previously described.

Such a rating on the basis of actually interrupted short-circuit kva would be meaningless in the case of Class E2 controllers with current-limiting fuses since the fuses interrupt the short-circuit current before it builds up to the crest value of the first major loop of the current wave. The actually interrupted kva is but a small fraction of the available short-circuit kva against which the controller is to protect the power system.

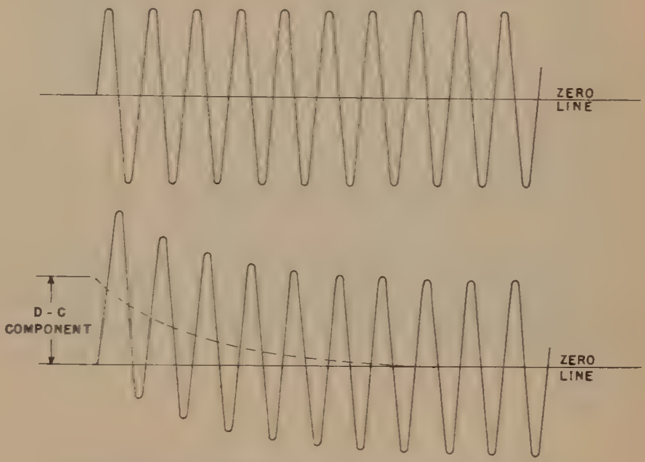

Fig. 6. Representative curves of a-c short-circuit currents. *Above:* symmetrical. *Below:* asymmetrical

To verify the controller rating by test, the controller is first short-circuited at its line terminals to determine the available kva of the power system. The short circuit is then removed and applied at the controller load terminals, and controller performance is observed. When applying controllers with current-limiting fuses, the maximum initial short-circuit current which may flow in one phase may be limited by the manufacturer's recommendations.

To establish the interrupting rating of high-voltage high-interrupting capacity controllers on a uniform basis, the NEMA standard stipulates that Class E1 and Class E2 controllers are rated on the basis of the available symmetrical rms short-circuit kva of the power system at the point of controller installation. This method of rating had been decided upon because it results in the simplest and most consistent listing of controllers by their manufacturers. It is entirely possible that an individual circuit interrupting device, when listed as a device, may have an interrupting rating different from the rating of the controller on which it is used. Thus, when applying controllers, it must be remembered that they are rated in terms of system capacity rather than actual interrupting performance.

UNDERVOLTAGE PROTECTION

High-voltage controllers being used in conjunction with comparatively large motors should be provided with undervoltage protection to avoid the hazards of inadvertent restarting after a power failure. Instantaneous or time-delay undervoltage protection may be considered.

Power companies have greatly improved the reliability of their systems, and considerable investments have been made in equipment designed to reduce the duration of power outages. A large percentage of outages last less than one second. The question then arises, why it should not be permissible for the controller to remain closed or to reclose automatically if the duration of the power outage does not exceed say three seconds, and if the power system capacity is such that full system voltage may be re-established without dropping all load.

As an example, consider a motor driving a fan. The inertia is fairly high, and during a power outage of short duration the loss in motor speed would not be appreciable. In such a case, time-delay undervoltage protection would be worth considering.

On the other hand, consider a motor driving a deep-well pump. When power fails, the water column would immediately drive the impeller backward, thus reversing the motor. If the motor remained connected to the line, it would be plugged upon reappearance of power, and serious damage to the shafting might result.

International Conference On Large Electric Systems (C.I.G.R.E.)

Paris, June 29 to July 8, 1950

This Conference, which will constitute the 13th Biennial Session of C.I.G.R.E., will be attended by 1500 delegates from 40 different countries. It will be devoted to discussion of all problems relating to the generation, transmission, and distribution of electric power. Executives and design and operating engineers in both the electric power and electric manufacturing industries will find particular interest in it. Of the 120 technical papers that are to be presented, 16 will be of U.S.A. authorship.

Arrangements have been made for a large and representative United States delegation, many of whom will remain for the Fourth World Power Conference, to be held in London July 10 to July 15, 1950. Also, the Swedish State Power Board has invited all U. S.–C.I.G.R.E. delegates for a tour of electrical installations in Sweden, from June 15 to June 26, 1950, preceding the C.I.G.R.E. Conference.

Further information and registration forms may be obtained from Frederic Attwood, Chairman, U. S. National Committee of C.I.G.R.E., Room 1781, 50 Church Street, New York 7, N. Y.

In the interest of standardization, with its mutual benefits to the manufacturer and the operator, the design of the controller should make possible, by a simple reconnection, the choice of either instantaneous or time-delay undervoltage protection.

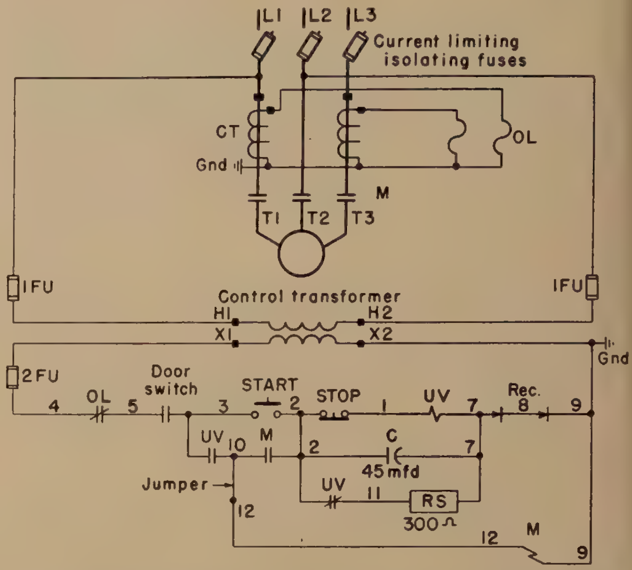

Fig. 7. Elementary diagram of high-voltage high-interrupting-capacity full-voltage starter. *M* is the line contactor, *OL* the overload relay, and *UV* the undervoltage relay

One design of a reconnectible undervoltage circuit is given in Fig. 7 which is the elementary diagram of a full-voltage starter for a squirrel-cage motor, Class E2, with current-limiting fuses. Undervoltage relay *UV* has a d-c magnet, and its coil is connected to the a-c control circuit through a half-wave metallic rectifier. Pressing the start button causes relay *UV* to pick up, and an interlock on *UV* energizes the coil circuit of line contactor *M*. If power fails, contactor *M* will drop out immediately because of loss of a-c control voltage. However, *UV* does not drop out immediately because the capacitor maintains d-c coil voltage for a predetermined time interval, so that *UV* drops out with a time delay. Should power reappear before *UV* has dropped out, *M* recloses since the *UV* contact has maintained the pick-up circuit for the coil of *M*. If the stop button is pressed, *UV* drops out immediately, since the *UV* coil circuit is interrupted. The capacitor is rapidly discharged through a normally closed contact of *UV*, so that *UV* will not pick up again when the stop button is released. The start button must be pressed again in order to restart the motor.

Connection *10-12* is a jumper on the terminal board of the controller. By reconnecting this jumper between terminals *2-12*, instantaneous undervoltage protection is obtained. When power fails, *M* drops out instantaneously. Even though *UV* drops out with a time delay, *M* cannot close again since the pick-up circuit for the *M* coil through the *UV* contact has been broken by the reconnection of the jumper. The start button must be pressed again before *M* can reclose.

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STEAM TURBINE FLOW-PRESSURE CHARACTERISTICS . . . Part II

Relationship of pressures in various stages and means of determining the turbine output as a function of steam conditions. Significance of turbine guarantees and the variables involved in correction factors

By J. KENNETH SALISBURY
Division Engineer, Thermal Power Systems Division
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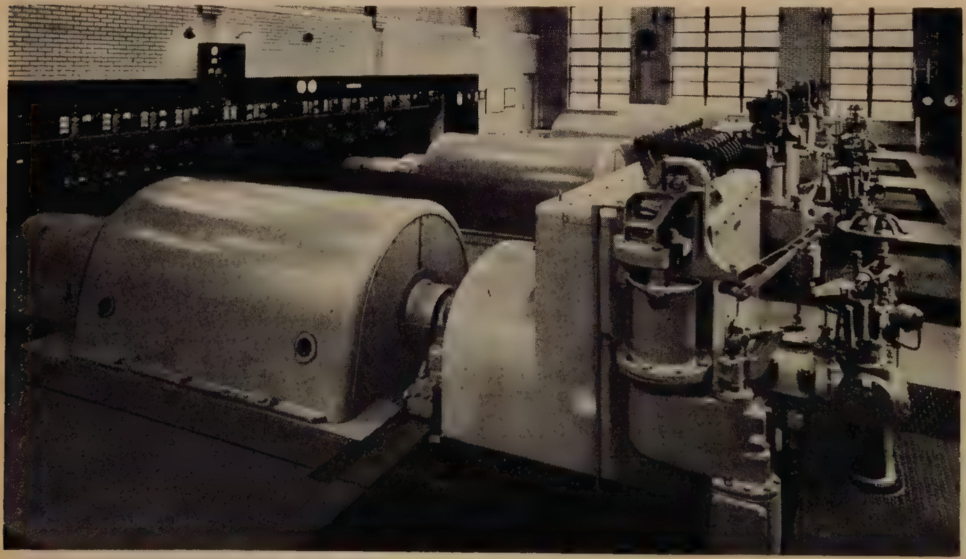
IN LAST analysis, all flow-pressure relationships in turbines revert to the principles set forth by the general flow equation. We have found, however, an equation for flow expressed in terms of the absolute temperature, of somewhat greater usefulness. This equation indicates that at a given initial temperature the flow is proportional to the initial pressure *provided the pressure ratio remains constant*. For the condensing-turbine analogy illustrated in FIG. 1, the pressure ratio between any two stages is constant over the flow range so that the flow-pressure relationship is a proportionality, except for minor temperature effects. This is primarily because the flow across the last stage of the turbine is greater than critical, so that the fourth-stage pressure in FIG. 1 is proportional to the flow, despite the fact that the exhaust pressure in space C is constant.



Four noncondensing steam-turbine-generators in an oil refinery

In a noncondensing turbine, the exhaust pressure is constant and much higher than in a condensing turbine. The flow across the last stage is usually in the restricted-flow range in modern noncondensing turbines. For these reasons the last-stage inlet pressure is *not* proportional to the flow, and the variation in first-stage shell pressure of a noncondensing turbine is considerably different from that in a condensing turbine.

Any variation in pressure caused at a given place in the turbine extends forward through the turbine, affecting each stage by successively lower amounts, until the first stage is barely affected at all. Bearing this in mind we may rationalize the variation in pressures with flow in a noncondensing turbine. Suppose, tentatively, that when the flow is decreased both first-stage shell pressure and exhaust pressure are decreased in proportion to the decreased flow. Under this condition, all pressures will bear a constant ratio to their previous value at the higher flow. If we now imagine that the exhaust pressure is arbitrarily raised above this tentative value to its original value, the pressure preceding the last stage will be increased by *less* than this fractional increase in the exhaust pressure, thus decreasing the fractional pressure drop across the last stage. The pressure ahead of the next-to-last stage will be raised a still smaller part of this fractional increase in exhaust pressure, etc., until finally the first stage will be increased by some percentage appreciably smaller than the percentage increase in exhaust pressure. This reasoning makes it clear that the last-stage pressure ratio changes considerably and that each succeeding higher-pressure stage undergoes a change in pressure ratio of progressively decreasing magnitude.

At very light flows, following the previous reasoning, the exhaust pressure and first-stage shell pressure

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This article will constitute part of the book *Steam Turbines and Their Cycles*, by J. Kenneth Salisbury, to be published by John Wiley and Sons, Inc. (New York). It is preprinted here by permission of the author and publisher.—ED.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR ould have been greatly decreased to obtain the light ow, and then the exhaust pressure would have been ised considerably, to revert to its original value: the rge change would cause a large decrease in the fraconal pressure drop across the last stage, and progresvely decreasing change in the other stages. The firstage pressure would be considerably increased over the ansitory value it hypothetically assumed. Thus the st stage would suffer a large decrease in available ergy, whereas the second stage would feel this effect o a much smaller degree. This is characteristic of highxhaust-pressure turbines. There is a wide variation in e energy on the last stage and a considerably greater ariation on *all* the stages than for a condensing turine, where the stage energies are essentially constant ecause of the unchanging stage-pressure ratios.

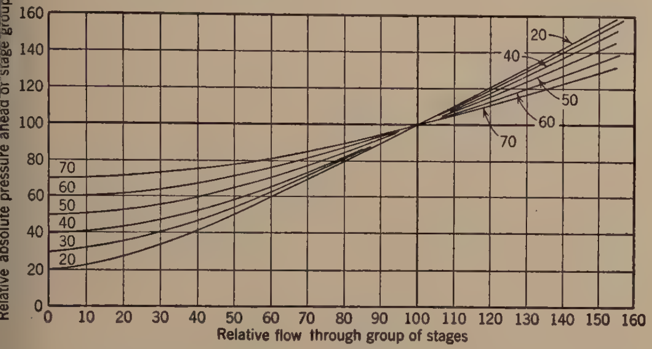

Fig. 5. Approximate variation in first-stage shell pressure with flow for noncondensing turbines. Assumptions: (1) at least five stages; (2) energy per stage is approximately equal at 100; (3) inlet temperature of the group varies along a line of 80-percent efficiency. Temperature correction may be applied to the inlet pressure for other variations

In the noncondensing turbine one must realize that he specific volume is essentially constant at the disharge of the last stage, so that the velocity must be early proportional to the flow through it, for constant ozzle area. Thus the stage available energy at ½ of esign flow is about ¼ that at the design condition.

The first-stage shell-pressure variation with flow in a oncondensing turbine differs greatly from the nearly inear relationship which applies in a condensing turine. This must, in fact, be true, because at zero flow he first-stage shell pressure of the turbine must be qual to the exhaust pressure. The approximate variaion of first-stage shell pressure with flow in typical oncondensing turbines is shown in FIG. 5, in which oth scales are relative. The horizontal scale is fraction f the design flow, it being assumed that at the design low the pressure ratios across the various stages are elatively constant. The parameter on the curves in IG. 5 is the design pressure ratio between exhaust and he first-stage shell. It is further assumed in FIG. 5 that he first-stage shell is sufficiently "remote" from the xhaust that the previously described effect of progresively decreasing change in pressure ratios occurs. The urves in FIG. 5, though not strictly correct for all types f noncondensing turbines, are sufficiently accurate for ost purposes and are an excellent guide to the variaion in first-stage shell pressure with flow. It is assumed that the temperature condition in the first-stage shell varies along an 80-percent-efficiency state line. An appropriate correction must be made for other efficiencies of the first stage, using the inverse-square-root temperature relationship to correct the pressure.

OUTPUT AS A FUNCTION OF STEAM CONDITIONS

The flow that a condensing steam turbine will pass varies in direct proportion to the initial pressure and in inverse proportion to the square root of the absolute temperature, *for a given control-valve position.** With control valves wide open on a turbine (or in any other fixed position), *if the turbine efficiency is constant,* the output of the turbine may, therefore, easily be determined for any specified steam conditions.

For the moment we shall neglect the variation in efficiency of the turbine. It is known that the output of a turbine is given by the following relationships

$$\text{Kw} = \frac{\text{Throttle flow}}{\text{Steam rate}} = \frac{\text{Throttle flow}}{\left(\dfrac{\text{Theoretical S.R.}}{\eta}\right)}$$

$$= \frac{\text{Throttle flow}}{\text{Theoretical S.R.}} \times \eta$$

We now know means whereby the throttle flow for any given steam conditions may be determined if any single value is known, and the theoretical steam rate may be obtained from the ASME tables. It must be borne in mind at all times that the relationships given assume the *position of the control valves to remain unchanged for the known and sought conditions.*

Suppose we know that a given turbine will carry 20,000 kw at steam conditions of 850 psig, 900 F, 1 in. Hg, and we desire to know the output when the steam conditions are changed to 750 psig, 850 F, 1.5 in. Hg. The following theoretical steam rates are obtained from the theoretical steam-rate tables:

Theoretical steam rate for 850–900–1 in. = 5.917

Theoretical steam rate for 750–850–1.5 in. = 6.368

The flow-passing ability at the lower steam conditions relative to the higher steam conditions is obtained by means of the relationship of flow to pressure and absolute temperature, thus:

$$\frac{W_2}{W_1} = \frac{765/\sqrt{1310}}{865/\sqrt{1360}} = 0.901$$

In other words, under the new conditions the turbine will pass approximately 10 percent less steam flow. The ratio of theoretical steam rates is:

$$\frac{\text{T.S.R.}_1}{\text{T.S.R.}_2} = \frac{5.917}{6.368} = 0.929$$

---

*For a noncondensing turbine, the direct proportionality of flow and pressure does not apply. Instead one must use the relationship in Fig. 5, in which the ordinate may also be interpreted as a *turbine* pressure ratio. One must bear in mind that these curves include the effect of temperature variation along an 80-percent state line. Other variations of temperature than this must be appropriately taken into account by the inverse-square-root relationship.

The ratio of outputs is then found

$$\frac{kw_2}{kw_1}=\frac{W_2}{W_1}\times\frac{T.S.R._1}{T.S.R._2}=0.901\times0.929=0.837$$

That is, under the new conditions the turbine will carry only 83.7 percent as much load as under the old conditions, assuming the turbine efficiency to remain constant.

Despite the fact that the assumption of constant efficiency may in some cases be appreciably in error, this method provides a quick means of determining to a first approximation the load that will be carried under other steam conditions. The true determination of the change in efficiency that occurs when steam conditions are changed involves additional effort on the part of the designer. He must determine the effect of the changed flow on the exhaust efficiency, and he must consider the effect of redistribution of stage energies within the turbine, if he is to arrive at an accurate value.

One ready improvement in accuracy that is easily applied and that deserves consideration at this point is the correction that results from change in the superheat at the inlet to the turbine. Tests have shown that the efficiency of a turbine improves approximately 2 percent (*not* 2 points) for each 100 F increase in superheat in the normal range of superheat. For the present example, it is found that the superheat at the new condition is 337 F, while at the original condition the superheat is 373 F, a decrease in superheat of 36 deg, which would correspond to a decrease in efficiency of 0.72 percent. Thus, instead of carrying 83.7 percent of the original load, the turbine would carry only 83.7 $(1-0.0072)=$ 83.1 percent. It must be remembered that the superheat correction applies only to condensing machines, since they are the only ones that suffer an appreciable moisture loss at the exhaust.

Another major effect can be described qualitatively. At heavy exhaust flows, increase in the flow (caused by a higher inlet pressure) causes a decrease in efficiency, and, conversely, at light flows an increase in flow causes an improvement. These effects range from negligible values to a few percent, depending on the exhaust design.

STEAM-TURBINE GUARANTEES

The manufacturer of a steam turbine is usually requested to guarantee one or all of the following characteristics of his machine:

(1). Steam rate at design exhaust pressure, over the load range

(2). Steam rate at other exhaust pressures within the expected operating range

(3). Maximum pressure of operation

(4). Maximum temperature of operation

(5). Total time at which turbine may be operated at stated higher temperatures

(6). Maximum guaranteed capacity with no extraction for feedwater heating

(7). Maximum guaranteed capacity with feedwater heating of its own condensate

(8). Maximum steam quantity which may be extracted for process (if specified)

(9). Pressure variation in process-steam extraction stage

(10). Stage pressures at various feedwater heating extraction points

(11). Guaranteed heat rates, based on a specified heater cycle, at the design exhaust pressure

(12). Guaranteed heat rates at other exhaust pressures, within the operating range

(13). Minimum load which may be carried

(14). Correction factors.

Among the various guarantees made for the steam turbine, by far the most important from the standpoint of performance is the heat-rate guarantee. The heat-rate guarantee is a true measure of the fuel consumption of the turbine cycle, whereas the steam-rate guarantee is not. The purchaser of the turbine may require that the manufacturer furnish him with complete data showing all extraction quantities, pressures, temperatures, etc., for all the guaranteed loads. He may, on the other hand, require only that the manufacturer furnish a heat-balance diagram indicating the heater cycle used, together with a curve showing the variation of heat rate with load. It is the author's opinion that it is of great value to users of turbines to develop within their own organizations people capable of making complete heat balances, primarily for the better understanding of the operation of the power plant that is obtained by calculation of the heat balance.

To permit ready checks of performance the manufacturer is sometimes asked to give correction factors, which are now to be considered at some length.

CORRECTION FACTORS

Correction factors for steam-turbine performance, particularly the nonextraction performance, are of such great value to the user that the entire philosophy upon which correction factors are predicated is given.

During the earlier days in the steam-turbine era, it was common practice for manufacturers to give correction factors in a very simple form. It was, for example, stated that "the water [steam] rate will improve 1 percent for each —— degrees change in initial superheat." The pressure correction was given in the same simple fashion, and it was implied that these corrections held throughout the load range. Actually, of course, this is not true. It is modern practice to supply with the guarantees a set of curves giving, on a strictly accurate basis, suitable correction factors applicable throughout the load range.

The nonextraction steam rate of a turbine is determined solely by two quantities: the theoretical steam rate and the turbine efficiency. The former is easily found from the theoretical steam rate tables. The turbine efficiency in all its ramifications, however, is known usually only by the turbine manufacturer. All correction factors are based on the fact that the turbine builder knows the *rate of change* of turbine efficiency with much greater accuracy than he knows its absolute value.

The efficiency of a given turbine depends almost exclusively on the volume flow (expressed in cubic feet per second) to the high-pressure end of the turbine and through the exhaust of the turbine.

In the modern method of quoting correction factors, variation in efficiency due to change in high-pressure-end volume flow has been eliminated by an ingenious assumption, namely, that the correction factors are given at *constant control-valve position*. If this is true, the volume flow to the turbine will be constant for all normal variations in initial conditions.

It has been shown that the weight flow to a turbine may be expressed as

$$\text{Weight flow} = K_1\sqrt{\frac{p_1}{v_1}} = K_2\frac{p_1}{\sqrt{T_1}}$$

for constant control-valve opening. In calculating pressure correction factors the turbine designer arbitrarily assumes an increment in pressure and a proportional increment in flow (at constant initial temperature). With this new flow, the exhaust volume flow may be determined and the exhaust efficiency properly adjusted, and a new over-all turbine efficiency may be determined. Correction factors thus determined may include not only the correction for improved theoretical steam rate but also the loss due to decreased turbine efficiency.

A typical initial-pressure correction curve is shown in Fig. 6. Note that at high volume flows there is a gain in turbine efficiency due to decrease in exhaust loss which makes the correction in steam rate less than the dash line representing the theoretical correction.

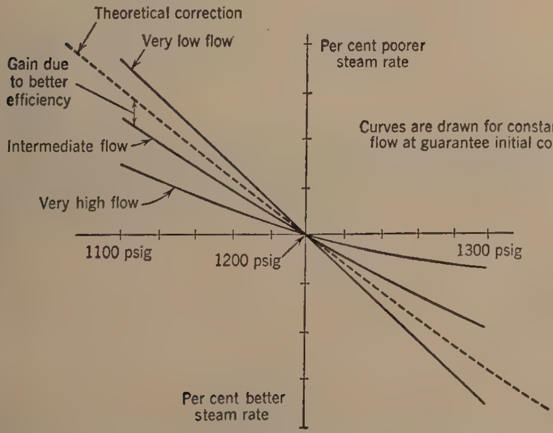

Fig. 6. Typical initial-pressure correction factors at constant initial temperature and exhaust pressure

It is, of course, necessary to supply a family of curves at different throttle flows, thus covering the range of exhaust volume flows. Any pressure correction curve, so constructed, is valid only at the exhaust pressures stated for it.

Temperature corrections are calculated in a similar manner and include the change in efficiency of the turbine due to changed moisture loss as well as the change in available energy. Ordinarily the change in exhaust volume flow is extremely small so that only one temperature correction curve need be given, as shown in Fig. 7.

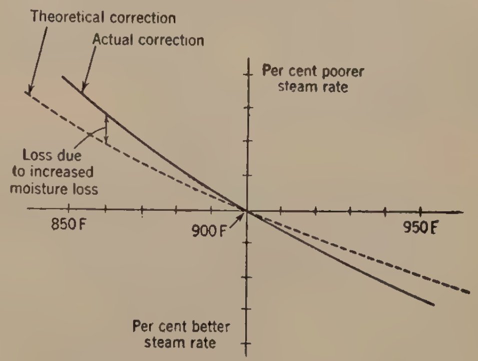

Fig. 7. Typical initial-temperature correction factors at constant initial pressure and exhaust pressure

Vacuum corrections are determined by calculating the change in exhaust volume flow and the resulting change in turbine efficiency. This change in turbine efficiency, when added algebraically to the change in available energy, produces the net change in steam rate plotted on the correction curve. Typical vacuum corrections are shown in Fig. 8.

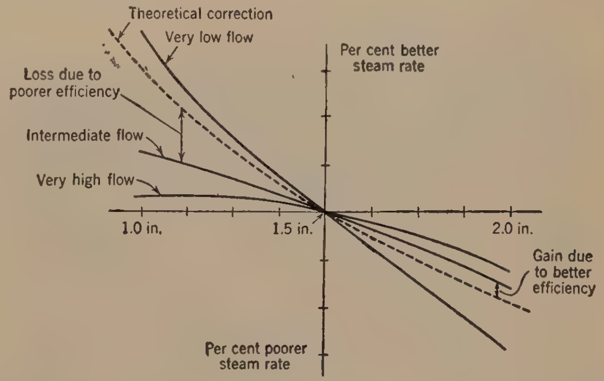

Fig. 8. Typical exhaust-pressure correction factors at constant initial pressure and temperature

Application of correction factors must be the converse of the method of obtaining them. Correction factors should be found from curves, for the test steam conditions. The corrections thus found are added* algebraically and applied to the test steam rate to obtain the steam rate on a guarantee basis. To obtain the load which would be obtained under guarantee initial conditions, it is necessary to calculate the flow which *would have existed* with guarantee initial conditions by using the pressure-temperature relationship, Equation (1), given in Part I. For example, if the test pressure is higher than the guarantee initial pressure,

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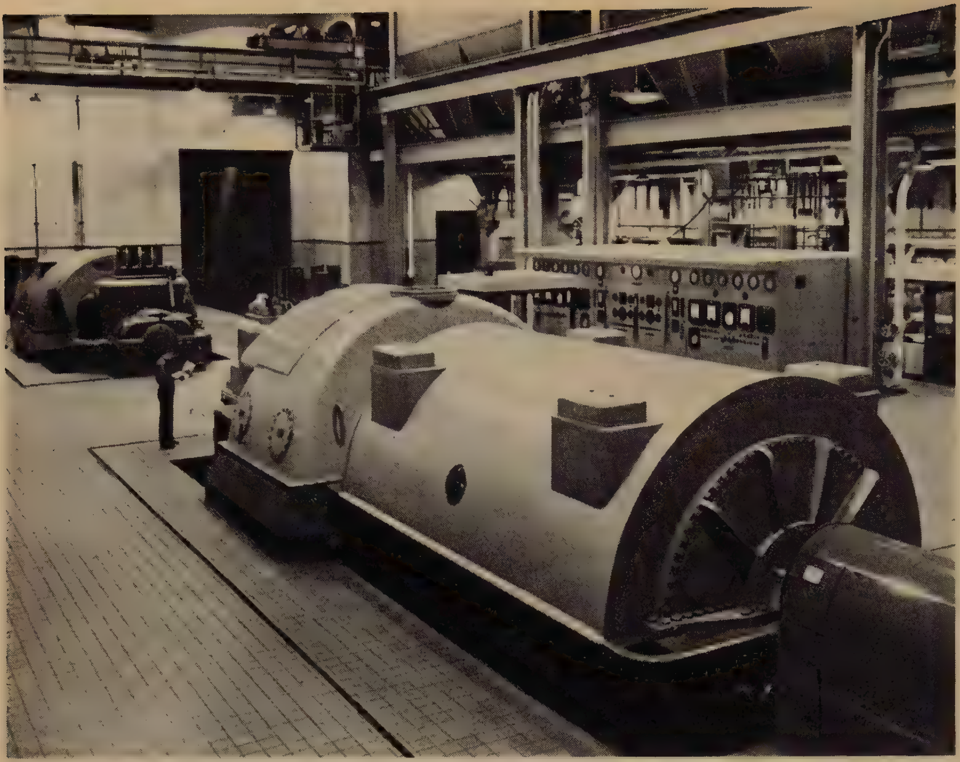
*For strict accuracy the fractional corrections should be added to unity and results multiplied. Usually this is an unnecessary refinement.



Two 40,000-kw 3600-rpm 21-stage turbine-generator units in a mid-western steam power plant

the test throttle flow must be reduced to the value which would have existed had guarantee initial pressure existed at the throttle.

The test flow having been corrected to guarantee initial pressure and temperature, the true "guarantee load" may be calculated by dividing the corrected flow by the corrected steam rate.

It will readily be seen that a series of tests run throughout the load range with variations from the guarantee initial conditions will, when corrected according to the above method, produce the exact shape of the load curve guaranteed, provided that the curve represents the true performance of the turbine.

Typical steam-rate curves are shown in FIGS. 9, 10, and 11 for a variation in each of the three conditions. FIG. 9 illustrates that, when the pressure is increased, the steam rate at corresponding control valve openings becomes lower and the "valve point" shifts to the right, producing more load because of the increased flow and improved steam rate.

FIG. 10 illustrates the variation in steam rate with initial temperature. When the temperature is increased, the steam rate improves and the improvement always more than offsets the slight decrease in flow which results from increased temperature, so as to give a net increase in load as the temperature increases.

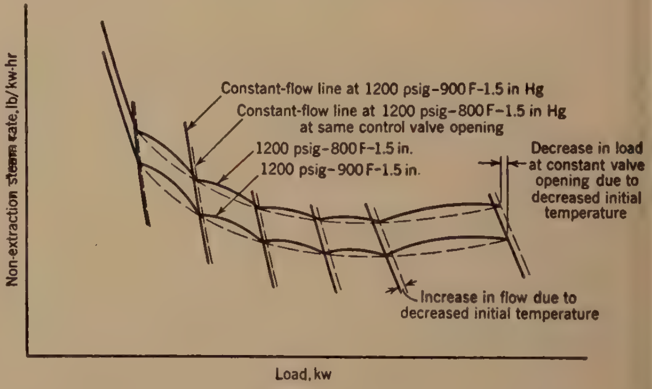


Fig. 10. Steam-rate curve showing effect of variation in initial temperature

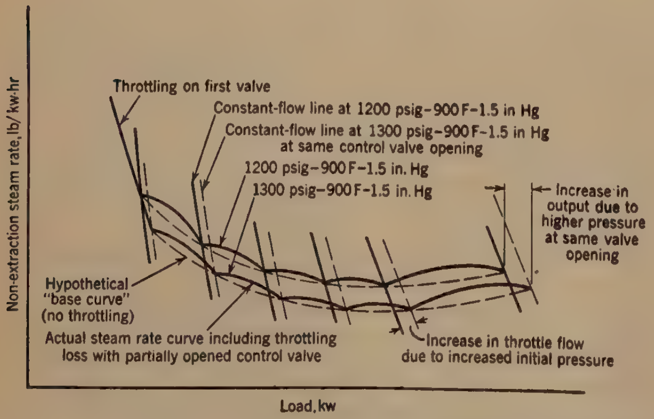


Fig. 9. Steam-rate curve showing effect of variation in initial pressure

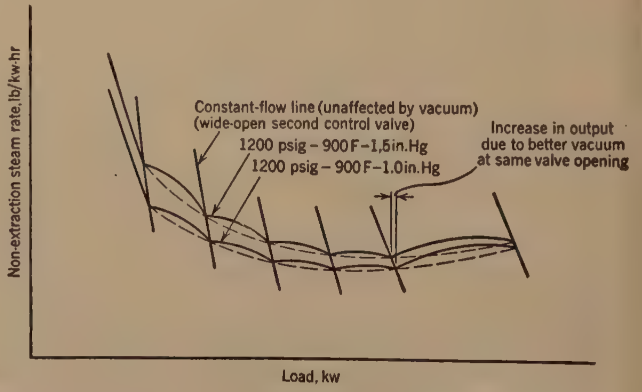


Fig. 11. Steam-rate curve showing effect of variation in exhaust pressure

TABLE I

VARIABLES INVOLVED IN CORRECTION FACTORS*

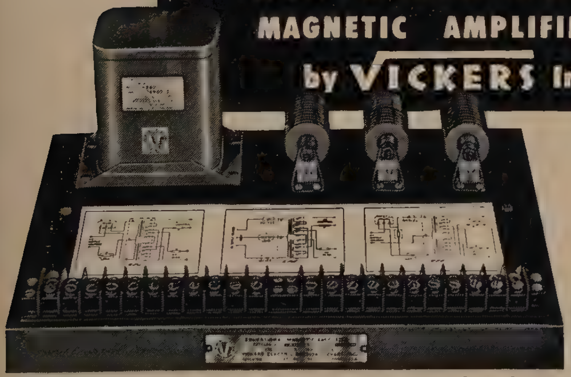
	Increased Pressure	Increased Temperature	Better Vacuum
1. Throttle weight flow	Increase	Decrease	No change
2. High-pressure-end volume flow	No change	No change	No change
3. Exhaust volume flow	Increase	Decrease	Increase
4. High-pressure-end efficiency	No change	No change	No change
5. Exhaust efficiency	(H) Decrease (L) Increase	Increase	(H) Decrease (L) Increase
6. Mechanical efficiency	Increase	Increase	Increase
7. Net turbine efficiency	(H) Decrease (L) Increase	Increase	(H) Decrease (L) Increase
8. Available energy	Increase	Increase	Increase
9. Steam rate	Lower	Lower	Lower
10. Output	Increase	Increase	Increase

*When given on the basis of constant control valve position.
H = high loads. L = low loads.

FIG. 11 illustrates the effect of change in vacuum on a steam-rate curve. Since initial pressure and temperature are unchanged, the valve points remain on "constant-flow" lines, but the steam rate improves by amounts given on suitable vacuum correction curves. Table I indicates all the variables involved in turbine correction factors. It has been necessary to differentiate in some cases between high and low loads because of the fact that exhaust loss increases at high loads with increase in volume flow. At very low loads, because the exhaust-end stages are suffering from lack of available energy, there is an increase in efficiency with increase in volume flow because such an increase provides these stages with the available energy required to make them operate more efficiently.

Thus the modern method of giving steam-turbine correction factors is a vast improvement over the old highly inaccurate method in that any test, when properly corrected, will truly represent the performance of the turbine on the guaranteed basis.

(Concluded)



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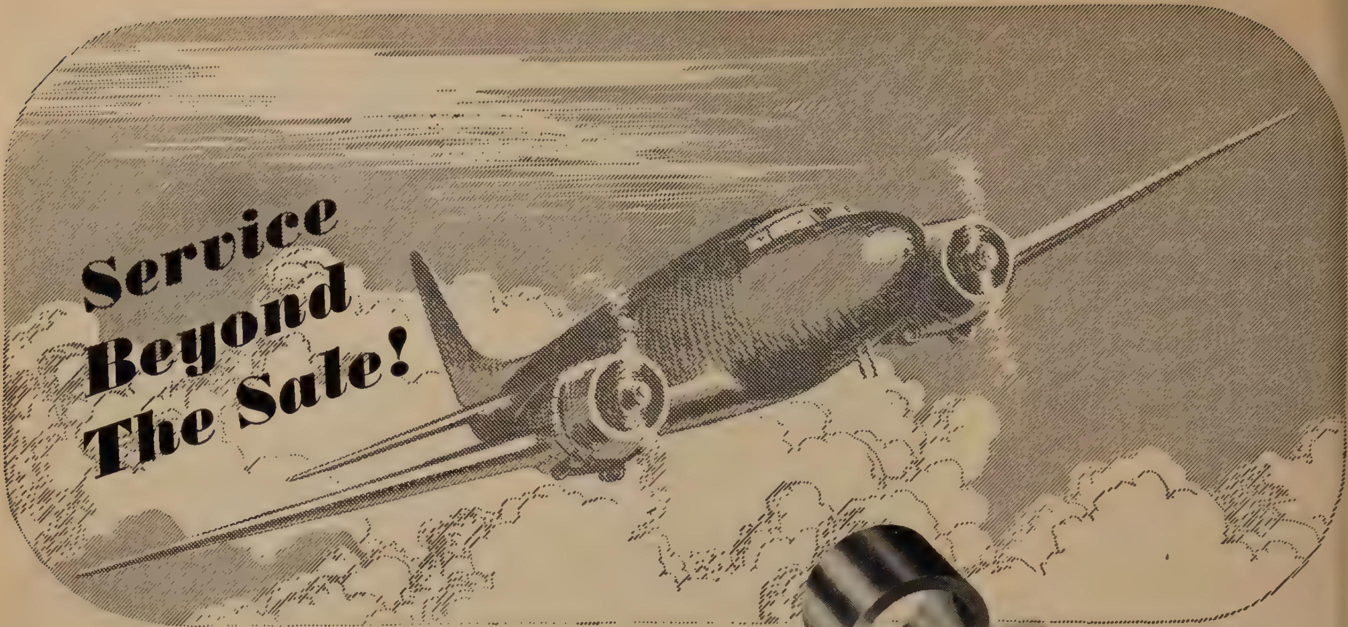
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By B. N. BOWERS

High-voltage Bushing Engineering Division, Apparatus Department
General Electric Company, Pittsfield, Mass.

IN THE first quarter of the 20th century the need arose for larger generating stations in producing electrical energy at greater efficiency. With greater concentration of power came the need for transmission lines to transmit that power to localities many miles distant from the generating station. Economic considerations then demanded higher voltages—voltages at 69 kv, 115 kv, and on up to 230 kv in the 1920's and to 287.5 kv in the 1930's—and many developments were necessary to design electrical apparatus which would handle these high voltages safely.

With the advent of high-voltage systems, the high-voltage bushing came of age. Its evolution from its ancestral copper rod and porcelain shell was rapid and it became a very important element of high-voltage electrical apparatus.

Oil-filled high-voltage bushings have been used on transformers and oil circuit breakers for more than thirty years and have an excellent service record. With recent trends in the design of electrical apparatus, though, some features of the older bushings have become outmoded. Because of this fact, a new oil-filled bushing has been designed to incorporate improvements which meet the requirements of modern apparatus.

Typical forms of the new bushings are shown in the accompanying illustrations. The cross-sectional drawings are views of a 138-kv capacitance bushing.

The new bushing,* which has now been in production for about three years, offers the following advantages:

(1). The bushing is hermetically sealed at the factory, thus preventing contamination or deterioration of the internal insulation and assuring long years of service. (The earlier bushing was ventilated to the atmosphere with its contaminating effects.)

(2). Servicing of the bushing is a relatively simple operation, in most cases consisting of inspecting the oil-level gage and cleaning the porcelain shells.

(3). The bushing has high mechanical strength; consequently, the hazards of shipping, installation, and general handling are considerably reduced.

(4). The bushing is smaller in diameter than the bushings of the earlier type and has reduced weight.

(5). Installation requires no special equipment; and lifting eyes in the support flange provide a ready means for attaching lifting cables.

DESIGN FEATURES

Years of service experience with oil-filled electrical apparatus have demonstrated that if the apparatus is completely dry initially, is filled with dry oil and then positively sealed, it will give many years of trouble-free service. The hermetic-sealed construction, which provides positive sealing, is accomplished by center-clamping and by the use of nitrile rubber gaskets. The sealed construction has been thoroughly service-tested in approximately 100,000 rubber-gasketed bushings of moderate voltage which have been placed in service in apparatus in the past sixteen years. Low-cost maintenance or servicing is also obtained by this hermetic sealing which maintains the initial high dielectric strength of the internal insulation throughout the years of service.

High mechanical strength results from center-clamping. The new bushings have withstood severe mechanical loadings under static conditions and also under interrupting tests applied to oil circuit breakers. In addition, reduction in diameter has been obtained by a center-clamped construction which requires no cemented-on clamping rings and by adjustment of internal insulation stresses to obtain maximum efficiency of the dielectric structure.

The major insulation of the bushing consists of treated-paper insulating cylinders and insulating oil which have proved so successful in the bushings of earlier types and in high-voltage transformers.

CONSTRUCTION

The center-clamping of the bushing places the porcelain parts under compression—under which stress porcelain is strongest. The porcelain shells are of high-quality, fully vitrified porcelain. They are of the multi-section construction with the sections glaze-welded together into one solid piece in the firing process. Ample mechanical strength is assured by a transverse loading test which is applied to each shell. In bushings in ratings above 230 kv, the top shell is in two large sections, the

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

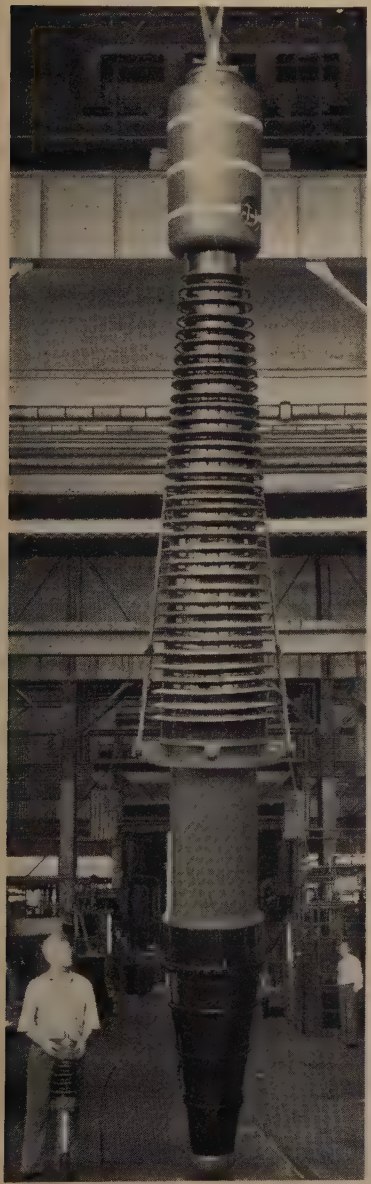
* This new bushing is identified by the trade designation Type F; the earlier type mentioned was the Type OF.

joint being sealed by a nitrile rubber gasket. The center tube is of high-strength copper threaded and sweated into the forged bottom washer.

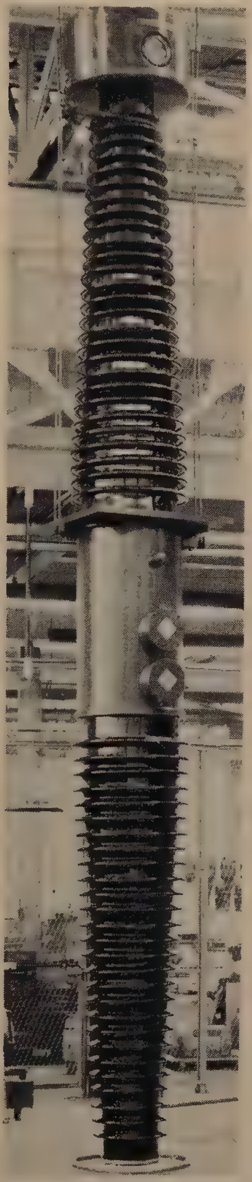
A high-pressure, multicoil spring assembly, consisting of many steel springs arranged concentrically around the center tube and enclosed in a toroidal diaphragm of seamless spun copper, is located just above the dome. The spring assembly compensates for thermal expansion and maintains safe clamping force on the structural parts and gasketed joints under all conditions of operation. The forged bronze cover is threaded to the center tube and applies the necessary clamping force against the spring assembly.

Ample expansion space above the insulating oil is provided by the dome or expansion chamber formed by a high-strength heat-treated aluminum casting. This space limits to a safe value the pressure at high operating temperatures. With the exception of the dome, no castings are used. High-strength brass forgings are used for most all nonmagnetic parts, insuring freedom from mechanical failure and leakage.

A magnetic oil gage, set in a recess in the side of the dome, indicates the level of oil in the bushing and is easily read from the ground under most conditions of operation.



A 360-kv bushing of the new type, for transformer service. Held alongside is a 34.5-kv bushing



High-voltage (360-kv) bushing for service in outdoor switchgear. This bushing contains two enclosed current transformers

The new bushing adapted to wall-entrance service. In this 92-kv unit the expansion chamber is a part of the support

The support is of fabricated steel, electric welded.

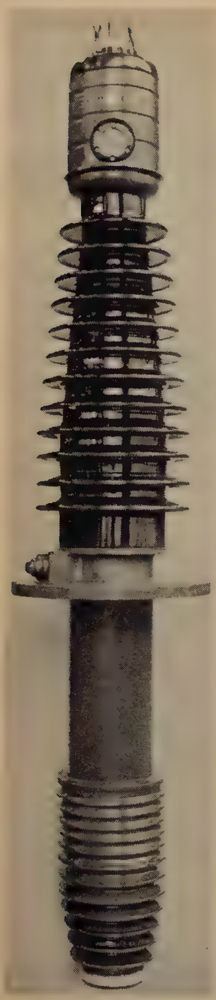
All the gaskets are confined in recesses in the metal parts. Gasket recesses in parts adjoining the porcelain shells are of proper depth to insure pressure-tight joints without metal-to-porcelain contact. The gaskets are all of a specially compounded nitrile-type synthetic rubber which is oilproof and waterproof and which retains its resiliency under all expected conditions of service.

Internal insulation is of alternate Herkolite cylinders and oil ducts in combination with a treated-paper-insulated electrode tube which surrounds the center conductor, insuring high dielectric strength under testing and operating voltages. The insulation cylinders are held in position by "T"-headed spacing blocks of kiln-dried maple which are locked in slots in the next-smaller-diameter cylinder.

Each of the insulation cylinders has a nonmetallic conducting Rescon equalizer embedded in the cylinder and so proportioned as to provide safe internal voltage gradients. The equalizer cylinders in combination with the internal terminal shield and the cylinder-embedded ground shield also maintain suitable voltage distribution in the external dielectric fields of the porcelain shells.

The terminal shield is of spun copper and is attached to the bottom of the dome. The ground shield consists of a concentric conducting Rescon plate embedded in the outer insulation cylinder and extends above and below the support. Connection with the support is made through a copper-foil electrode wound into the cylinder with the Rescon and a flexible copper braid.

In bushings equipped with a capacitance tap, the outer insulation cylinder, known as the capacitance cylinder, is made of Herkolite and has two concentric, nonmetallic conducting plates of Rescon which form the tap and ground plates. These plates extend above and below the support a few inches. A copper-foil electrode is wound into the cylinder in contact with each Rescon plate to provide means for making contact



New bushing for oil-circuit-breaker service. This is a 138-kv bushing. Various details of construction of this bushing are shown in the accompanying sectional drawings

for tap and ground connections, consisting of a spring contact terminal and a soldered copper braid, respectively.

When the bushing has been assembled, it is subjected to a vacuum treatment at a pressure of less than 1000 microns of mercury at a temperature of 110C for several hours and then is filled with degasified oil of high quality. After the oil level has been adjusted, the bushing is sealed pressure-tight at the filling hole in the dome, with a pressure cushion of dry nitrogen gas above the oil level.

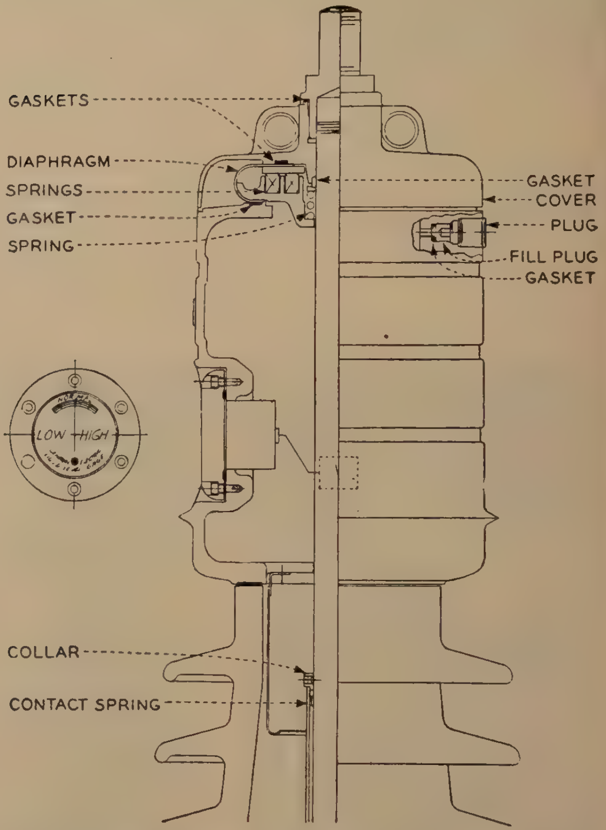
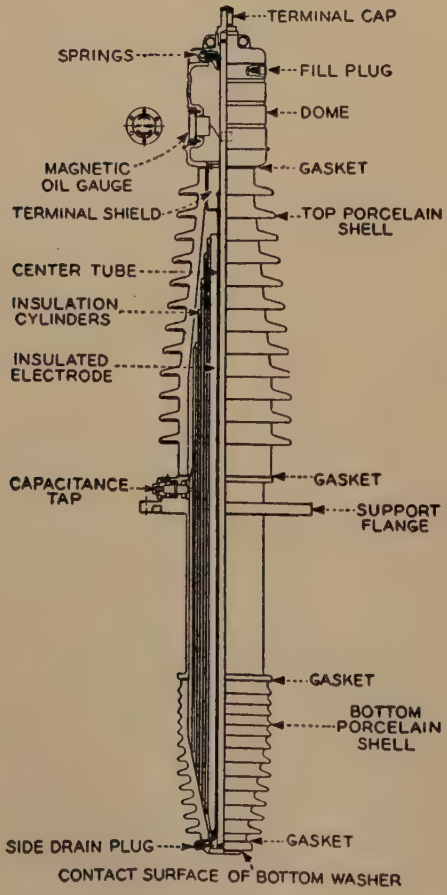


Diagram of the dome assembly of a 138-kv bushing showing construction of the expansion chamber



Outline and sectional diagram of 138-kv bushing showing various components

APPLICATION

These bushings are available for transformers in standard ratings from 115 kv to 360 kv. With capacitance tap for oil circuit breakers, the bushings are available in ratings from 115 kv to 196 kv.

Bushings rated 115 kv to 230 kv have mounting flanges which are interchangeable with the superseded bushings. The elimination of the bottom clamping ring has permitted shortening the bushings approximately three inches. For replacements in oil circuit breakers, a suitable adapter can be provided to compensate for the shortened length and thereby readily adapt the new bushings to older breakers.

For transformers, bushings in these ratings which have detachable cable terminal parts may be interchanged with the old bushings having the same ground sleeve length, since the terminal studs which are brazed to the transformer leads are interchangeable. Differences in height between the old and new bushings in some instances may require changing the length of the cable leads.

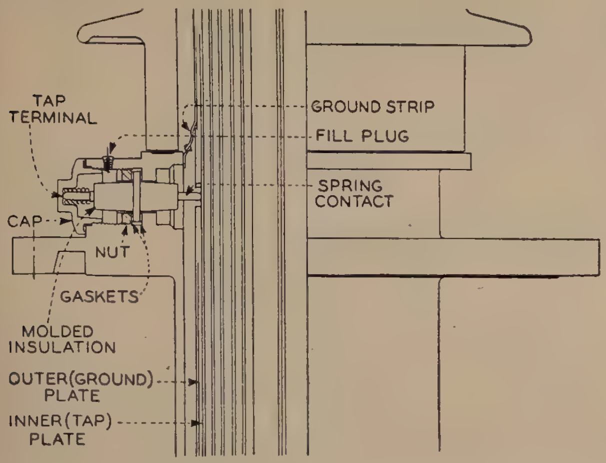


Diagram of the capacitance tap of a 138-kv bushing of the new type

CONCLUSION

The new bushings provide high reliability, small diameter, ease of installation, and low maintenance. They meet AIEE and NEMA standards and are designed to meet the needs of modern apparatus. It is expected that they can be readily applied to apparatus with a minimum number of designs and thus contribute to the trend of standardization and its far-reaching benefits.

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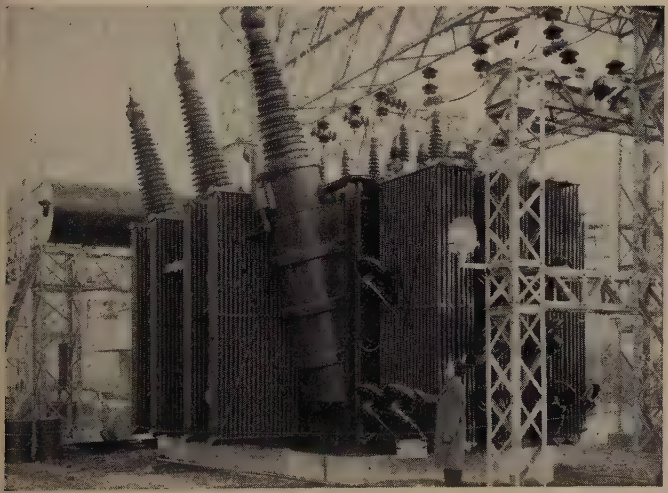

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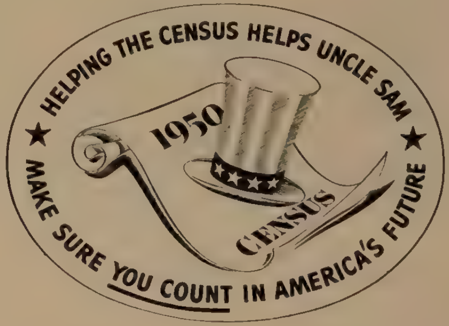
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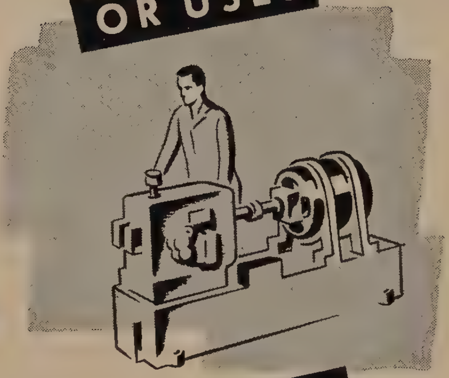

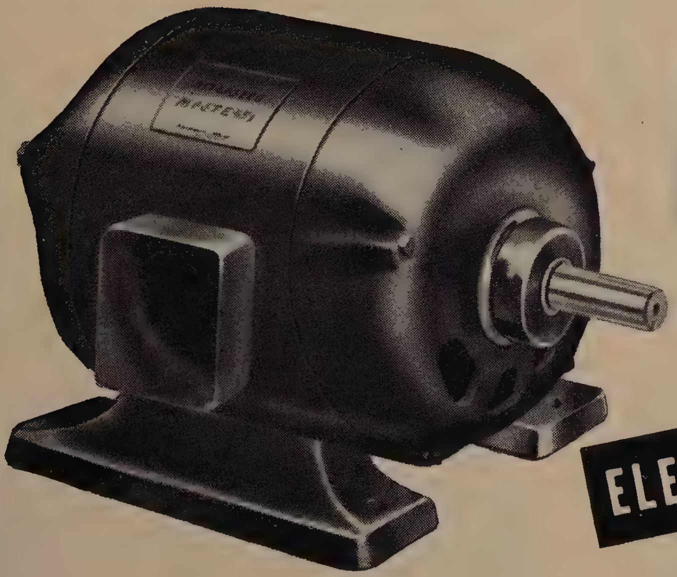

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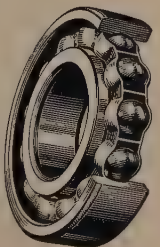

PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part XV

Remedial measures that offer prompt solution when applied to protective-atmosphere ailments that are sometimes encountered during operating procedures. Possible sources of impurities and how to locate them

By A. G. HOTCHKISS and H. M. WEBBER

Industrial Heating Divisions, General Electric Company

THE use of protective atmospheres, already widespread in industry, is growing constantly. Earlier parts of this serial have presented basic theoretical considerations, types of atmosphere gases available, methods of generating and handling gases, and typical applications. The information has been compiled for the purpose of facilitating the practical application of this modern industrial tool.

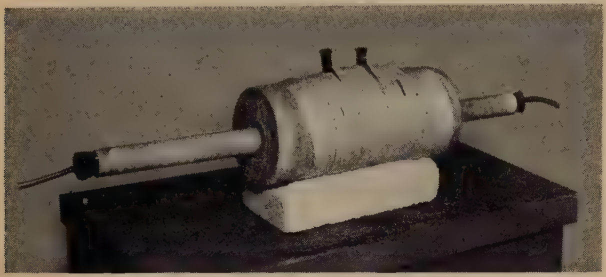

Fig. 155. Quartz-tube electrically heated furnace for determining whether an atmosphere gas has oxidizing properties

Even though the basic rules are comparatively simple, sometimes in the development of a new process, in starting a new installation, or in operating and maintaining an existing equipment undesirable or unexpected results may be obtained. When difficulties do develop, a quick solution is usually possible if the reason for the trouble can be readily ascertained. This part gives practical hints and suggestions on where to look for trouble and what to try as possible remedies for protective atmosphere ailments.

In Part I* consideration was given to two general types of surface changes. In diagnosing furnace troubles, it is desirable also to separate applications into the same two classes: oxidation and metallurgical changes.

Oxidation, which results in scaling or discoloration of ferrous metals, is caused by the following atmosphere constituents: oxygen, water vapor, and carbon dioxide. Nonferrous metals also are discolored by oxygen and sulfur.

A *metallurgical* change which results in decarburization, or carburization, is caused by: oxygen, water vapor, and carbon dioxide; or carbon monoxide and hydrocarbons, such as methane, respectively.

Three of the constituents are common to both types of surface changes; the degree to which they may be present and the method of analyzing the trouble, however, differs greatly for the two types of surface changes. To form the general picture, it is desirable to list after each constituent the possible source of each impurity, as follows:

(A). *Oxygen* may come from:

(1). Air leakage into the furnace chamber
(2). Air carried into the furnace with the work
(3). Free oxygen in generated atmosphere gas
(4). Oxygen in the atmosphere from the cooling water (direct-contact cooling methods).

(B). *Water vapor* may come from:

(1). Oxide on the work entering the furnace (in contact with a reducing gas)
(2). Surfaces of the parts entering the furnace
(3). Atmosphere gas being introduced into the furnace chamber
(4). Re-formation of the atmosphere gas under heat (water-gas reaction)
(5). Leakage from water-jacketed members (cooling chamber, door fronts, etc.).

(C). *Carbon dioxide* may come from:

(1). Atmosphere gas as generated
(2). Air leakage if atmosphere gas contains CO
(3). Re-formation of the atmosphere gas under heat (water-gas reaction).

(D). *Sulfur* may come from:

(1). Fuel gas used in atmosphere-gas producer
(2). Air which is burned with the fuel gas
(3). Lubricants on the surface of the work being treated
(4). Brickwork and insulation of the furnace.

(E). *Carbon monoxide* may come from:

(1). Atmosphere gas as generated
(2). Vapors from oil on the work.

(F). *Methane* may come from:

(1). Atmosphere gas as generated
(2). Lubricants on the work
(3). Deliberate addition to the atmosphere gas after generation.

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*The following will facilitate the location of material published in this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18) to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None
Part X	Sept. 1949, p. 38	98 to 108	None	XVII to XIX	(24) and (25)
Part XI	Nov. 1949, p. 30	109 to 116	None	None	(26) to (29)
Part XII	Dec. 1949, p. 46	117 to 131	None	None	(30) to (33)
Part XIII	Feb. 1950, p. 43	132 to 149	None	None	(34) to (42)
Part XIV	Mar. 1950, p. 36	150 to 154	None	None	(43) and (44)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

When the various possibilities for contamination of the protective atmosphere are known, the next step is to determine which impurity is the cause of the trouble. Many times this is evident from an inspection of the work being treated; it is necessary at other times, however, to run special tests to determine the cause.

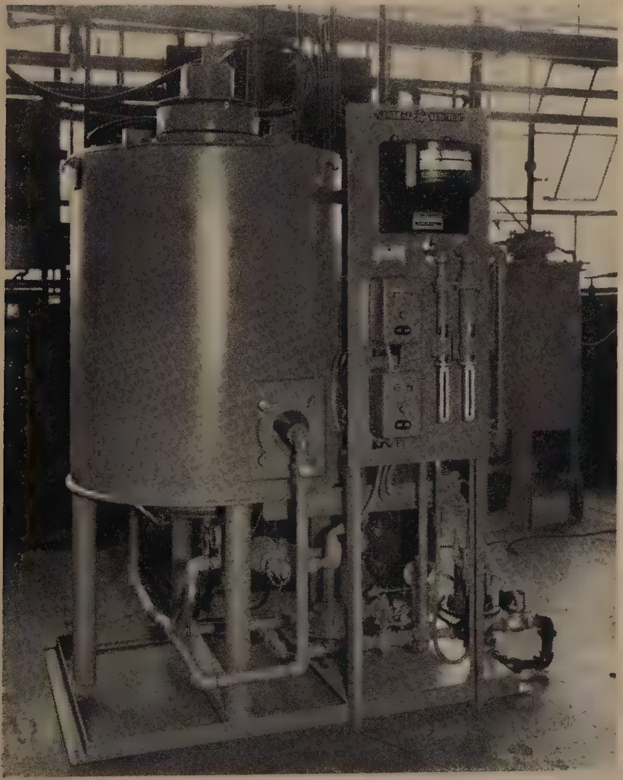
TESTS FOR OXIDATION OR OTHER DISCOLORATION

NONFERROUS METALS

Copper is probably the most common and important nonferrous metal being treated in protective atmospheres. It is unaffected by water vapor or carbon dioxide. The two constituents that do cause trouble are: oxygen, which makes copper oxide; and sulfur, which produces copper sulfide. The surface discoloration resulting from these two impurities can often be differentiated by visual appearance. If the oxidation is substantial, it will be apparent in the form of a loose scale or as a reddish surface film. If the oxidation is light, its color may be a light pink and sometimes iridescent.

Test for Distinguishing Sulfide from Oxide

(I). A rather certain test for distinguishing copper sulfide from an oxide is to immerse the discolored sample in a pickling solution of dilute sulfuric acid. If the discoloration is removed rapidly and a clean copper-colored surface remains, the discoloration is an oxide. The discoloration caused by sulfur may have an appearance very similar to a light oxide, but generally has a bluish or blue-gray color. A more positive identification is the pickling method just mentioned. If the discoloration is not readily pickled away, it is almost certain to be sulfide, rather than oxide.



Thermalene gas producer, rated 500 cfh, for providing nondecarburizing protective atmospheres. It functions with an endothermic reaction of hydrocarbon gas and air in a catalyst-filled retort

Effects of Oxygen. The annealing atmosphere generally contains small amounts of hydrogen, 0.5 to 1.0 percent; thus any infiltration of oxygen to a small degree, which would normally oxidize the copper, is neutralized at elevated temperatures; for example, any copper oxide present when the temperature is about 350 F or above is reduced. Between 350 F and 150 F, the copper may become oxidized upon cooling. The oxidation rate below 150 F is negligible, and therefore copper is generally cooled to this point before being brought from the furnace into contact with the air. Thus the cooling cycle of a copper-annealing furnace is critical within the range of 350 to 150 F, because any oxygen infiltration in this range will produce an oxide on the metallic surfaces which cannot be reduced by the gas.

Effects of Sulfur. Sulfur in the form of sulfur-dioxide gas has little effect on copper and other nonferrous metals. In general, sulfur that produces a reaction is in the form of hydrogen sulfide, which is very active toward copper, nickel, and silver, or alloys rich in these metals. If the atmosphere gas used contains no hydrogen, then sulfur, if present in the drawing or rolling lubricant or in other forms, would cause no discoloration; a small amount of hydrogen would combine with the sulfur, however, to form the active hydrogen sulfide. It has been reported that this conversion of sulfur in the presence of hydrogen to hydrogen sulfide at heat-treating temperatures is catalyzed by the presence of iron.

Tests for Presence of Sulfur

(II). A simple test for determining the presence of hydrogen sulfide (H_2S) in the protective-atmosphere gas is to wet a piece of white filter paper with a saturated solution of lead acetate and hold this paper in a small stream of the gas. Hydrogen sulfide will change the color of the paper from white to a light brown or black. The degree of color and the rate at which it forms give some indication as to the H_2S concentration. For the gas to be considered sulfur-free, the test paper should show no color after about one minute contact with the gas stream.

(III). Nonmetallic materials—such as brick, mortar, insulation, lubricants, etc.—which are suspected of containing sulfur, can be tested by heating in hydrogen and checking the discharge gas for hydrogen sulfide by Test No. II. A simple method is to use a small furnace with a quartz or ceramic tube retort as shown in FIG. 155. The hydrogen should be passed through the empty tube, but checked first to see that it is free of hydrogen sulfide.

(IV). Metallic materials which have been discolored or attacked on the surface can be checked for presence of sulfur by the following method: Obtain a 10 percent solution of hydrochloric acid in water, a beaker, granular metallic zinc, and lead-acetate paper. Into the beaker pour a small amount of the acid solution, add a small amount of the zinc, and place the lead-acetate paper over the top of the beaker. A clean paper is a zero check for H_2S. Drop the sample to be tested into the beaker and again cover with lead-acetate test paper. Reaction of the zinc with the acid will give off nascent hydrogen, which will combine with any sulfur present on the sample to form hydrogen sulfide; this in turn will be indicated as a discoloration on the test paper.

Effects of Zinc. Alloys rich in copper will react, in general, similarly to copper. However, when the percentage of alloying element, such as zinc, is high, as in yellow brass, discoloration may result from zinc distillation. This is usually evident from visual inspection, which will show a deposit ranging from a light gray to white on the surface of the metal, along with a roughening of the metallic surface. The zinc film on parts can become oxidized by small amounts of oxygen, water vapor, carbon dioxide, and carbon monoxide in the protective atmosphere.

FERROUS METALS

Clean, bright ferrous metals entering a protective-atmosphere furnace sometimes emerge discolored; and, to learn the cause, a little detective work is necessary.

The amount of sulfur present in normal protective atmospheres does not have any effect on the surfaces of ferrous metals.

Oxidation of ferrous metals can be divided roughly into two classes: that produced at low temperature in the bluing range below 900 F, and that produced at higher temperatures.

In the low-temperature range, either oxygen or water vapor can produce oxidation and discoloration, with either source resulting in about the same final appearance. Such discoloration, in the form of bluing, generally takes place during the cooling cycle.

Oxidation at high temperatures ordinarily goes beyond the bluing stage and results in etching or scaling. Oxygen tends to produce a light gray to black dull-appearing scale which loosens upon cooling, whereas excessive moisture produces a more tightly adhering oxide with a darker, sometimes glossy, appearance.

The position in the furnace at which oxidation occurs can be determined by examining the product. For example, if steel parts emerging from a continuous furnace have a bright but etched or roughened surface, it indicates that oxidation from some source has occurred near the front of the furnace during the heating-up period, followed by reduction of the oxide and proper protection from further oxidation during the cooling cycle.

Tests for Causes of Oxidation

(V). One method for determining the cause of oxidation is to put a test piece of bright copper through the furnace with the steel. Because copper is oxidized by oxygen but not by water vapor, its behavior as compared with that of the steel should indicate which impurity is present. But one must remember not to be misled by a possible sulfur discoloration on the copper, as previously mentioned.

(VI). Another method of checking either the atmosphere gas as generated or that contained in a furnace chamber, for oxidizing properties, is by the use of a small tube-type test furnace, such as that in Fig. 155. The furnace is brought to a red heat and the gas to be tested is introduced at one end in sufficient quantity to purge the tube of all air. After the tube is properly purged, the stopper is removed at the discharge end and small samples, such as wire or strips of bright steel or copper, or both, are pushed into the furnace and the stopper is replaced. The samples should be longer than the furnace so that both ends remain cold while the center is brought to furnace temperature.

A few minutes after temperature is reached, the power to the furnace is shut off to allow cooling. A sufficient flow of atmosphere is maintained to prevent the entrance of air. After the furnace has cooled to at least 200 F, the samples can be removed for inspection, and they will indicate by their color whether the atmosphere can maintain a bright surface or produce discoloration. The type of discoloration obtained, as mentioned, should indicate whether the trouble is caused by oxygen or moisture. In the absence of a test furnace and quartz tube, a similar test can be conducted in a piece of iron or alloy tubing with samples at a spot near the center of the length, by applying a heating torch bringing the tube up to a red heat for two or three minutes, and then allowing it to cool. The tubing used should be carefully cleaned on the inside to remove any oil and dirt, and should be further conditioned by passing the atmosphere gas through the empty tube while heating as much of it as possible to a red heat, and then cooling with the atmosphere gas still flowing.

Discoloration During Hardening. Parts that are being scale-free hardened in controlled atmospheres, by quenching from the discharge end of a conveyor through a chute sealed in oil (to avoid contact with the air), are generally free from oxidation. Sometimes, however, they are found to be discolored. This discoloration may be a carbon film or it may be a film of dirt resulting from heavy oil or dirt that was on the parts before they were placed in the furnace. Such a sludge deposit can usually be rubbed off, leaving a bright surface.

A discoloration that is a true oxide film is usually caused by either water or air in the quenching oil. A series of tests on plain carbon steel quenched in mineral oil, results of which are shown in Table XX, indicates that discoloration caused by water or air, or both, increases with the cross section of the piece and with the temperature at which the work is quenched. This discoloration from the quench may be uniform; it may appear as splotches; or it may be on only one side of the piece. Water, the cause of most discolorations, may come from condensate from the atmosphere, or from water leaks in the oil-cooling system or water-cooled quench chute. Air sometimes enters through packing glands of oil-circulating pumps and appears as foam on the surface of the oil. Water can be removed by boiling the oil and circulating it to let the steam escape.

If carbon-steel parts are clean when they are placed in the furnace, if the protective atmosphere within the furnace is right, and if the quenching oil is clean and free from air and water, even the parts of heavy sections can have clean, bright surfaces after hardening. It must be remembered, however, that alloy steels containing one percent or more of chromium will become selectively oxidized, turning dark after treatment in the normal protective atmospheres.

Effects of Time and Temperature. Usually, the degree of oxidation of a metal is a function of time and temperature; if heated and cooled rapidly, little oxidation occurs, even in air. An atmosphere which would cause bluing of steel in a long-cycle bell-type annealing furnace, due to excessive water vapor, would also produce bright steel from a continuous furnace where the cooling requires minutes instead of hours.

Oxidation due to water vapor and carbon dioxide is dependent on the gas equilibrium with respect to the gas, the material, and the temperature. With respect to iron, the amount of water permissible is dependent on the amount of hydrogen present, and the carbon dioxide allowable is determined by the value of the carbon monoxide. This equilibrium condition is described in Part II and illustrated by the curves shown in FIG. 10. The curves indicate the effect of temperature, showing that although a certain atmosphere may prevent oxidation at a high temperature, the parts may oxidize while being cooled in this atmosphere at a lower temperature.

TESTING FOR LEAKS IN FURNACES

Because most furnace atmosphere troubles are caused by leakage (infiltration) of air, by moisture resulting from the chemical combination of infiltrated air and the atmosphere gas, or by water leakage, the following suggestions are given for testing for leaks in furnaces:

TESTS FOR AIR LEAKS

Bell Furnace

(VII). Assuming a liquid-sealed retort, the air-leak test can be made with the aid of a pressure gage. Fill the retort with gas or air, and then shut off both inlet and outlet valves. A reduction in pressure will indicate a leak, of course, assuming that the temperature of the retort remains constant.

(VIII). If the incoming atmosphere is metered, shut off the outlet valve and hold the retort under pressure. Any leakage should be indicated on the meter.

(IX). If a retort is thoroughly purged of air and filled with a flammable gas, leaks may be found by searching at welded seams, stuffing boxes, etc., with a torch which will ignite the leaking gas.

(X). Build up a gas or air pressure of 3 or 4 in. water column within the retort and apply soapy water to all seams, welds, and points where leaks could be expected. The leaks will cause bubbles to appear.

(XI). Air may be drawn into a perfectly tight retort and base by improper operating procedure. When a hot furnace is removed from a loaded base and the retort is suddenly exposed to room air, it begins to cool rapidly. This cooling effect shrinks the volume of the atmosphere gas in the retort and, if this shrinkage takes place faster than additional gas can enter from the inlet pipe, a negative pressure is produced. This reduced pressure may suck in air through the exhaust vent or, if great enough, it may suck air through the seal chamber. To reduce the possibility of such trouble, the furnace chamber should be removed so slowly that negative pressures are not produced. This effect can be determined by use of a simple U-tube pressure indicator connected to the inside of the retort chamber, or by watching the level changes in the liquid seal.

Box-type or Horizontal Continuous-type Furnaces

(XII). With the furnace at normal operating temperature and filled with a flammable gas, close all doors and openings, blocking them shut, if necessary, to establish a slight positive pressure within the furnace chamber. The test is then made by a flame torch, going over all welds, packing boxes, and other possible points of leakage. Most atmosphere gases burn with a light-blue, nearly colorless flame, which is difficult to see in daylight. A test made at night in a somewhat darkened room is effective in determining leaks by this method.

(XIII). Any point of leakage above the level of the bottom of the door opening will generally cause a loss of atmosphere gas in normal operation. Such leaks, unless large, are of minor importance because in the top portions of the furnace the leakage will be outward and therefore will not be a source of air infiltration at those points.

(XIV). Any leaks found below the bottom of the door opening should be considered air leaks. Leakage at this point is important because, as soon as the door is opened and the pressure reduced in the furnace chamber, air will enter any such opening and

TABLE XX

SURFACE COLORS OBTAINED BY QUENCHING CARBON STEELS IN MINERAL OIL CONTAINING WATER OR AIR AS IMPURITIES

Thickness of Sample (Inches)	Volume Percent Water in Quenching Oil				Air in Oil
	0.005	0.05	0.20	0.5*	
0.010 0.040 0.125 0.250 0.50 0.75	Bright Straw ↓ to ↓ Blue	Bright Deep Straw ↓ to ↓ Deep Blue	Bright Blue ↓ to ↓ Blue Black	Straw Deep Blue ↓ to ↓ Dull Black	Bright Bright Straw ↓ to Deep Straw

*At this concentration the oil changed from its natural color to a brick-red color.

can be the cause of discoloration of the work going through the furnace.

(XV). Air leakage during normal operation of a furnace can be checked by analyzing a gas sample taken from the furnace chamber shortly after a door has been opened. This analysis should be compared to that of the inlet gas. Air leakage into the furnace would show a definite decrease in the amount of CO and H_2, with a corresponding increase in CO_2 and H_2O.

FIG. 156 illustrates the results obtained in a typical box-type furnace with gas-flame curtain and protective atmosphere of about 20 percent CO, 0.0 percent CO_2, 3.0 percent H_2, and 77.0 percent N_2, dew point −10 F. The 20-in. high door was opened, held 30 sec and closed, after which the CO_2 content within the furnace increased from 0.0 percent to 6.7 percent in 1.4 min, because of infiltration of oxygen and CO_2 from the room air and gas-flame curtain. Then the CO_2 dropped back to 0.0 percent in 7 min because of purging action of the atmosphere gas.

(XVI). Air may enter furnaces when doors are opened to charge or discharge work. This may be caused by drafts which blow air into the furnace-door opening, improper distribution of the flow of atmosphere gas to both ends of the furnace, or improperly operating flame curtains at the doors. Such difficulties usually can be determined by visual inspection. The required rate of flow of atmosphere gas is sometimes related to the volume of the furnace. For FIG. 156, the furnace had a door opening 27 in. wide by 20 in. high and the volume inside its lining was about 42 cu ft. The rate of flow of atmosphere gas was about 400 cfh. With higher or lower flow rates, the maximum CO_2 content would have been less or more respectively, and the time required to purge back to 0.0 percent CO_2 would likewise vary in the same manner.

EXCESS MOISTURE IN FURNACE

Methods for Reducing Condensation and Leakage

(XVII). Excess moisture may appear as condensate in the bottom of a cooling chamber. This collection of water will be heated by hot work entering the cooling chamber causing steam to form which might oxidize the work. To reduce the possibility of condensate forming at this point, raise the temperature of the water-cooled jacket to about 150 or 170 F by decreasing the water flow through the chamber. Maintaining such temperatures will cause the condensate to evaporate.

This condensate may be caused by air leakage which will combine with the hydrogen in the protective atmosphere to form water vapor in the furnace. Another possibility is that the entering atmosphere gas is not being properly cooled at the producer and is carrying excess moisture with it into the furnace. Elimination of air leaks and correction of the cooling difficulty should dispose of these sources of moisture.

(XVIII). Excess moisture in the furnace and/or its protective atmosphere may be caused by direct water leakage from water cooling chambers or cooling jackets around doors, to the inside of the furnace. Such leakage usually can be found only by visual inspection. This possibility must be considered if it has been found that moisture is not coming from the sources indicated in Test XVII.

(XIX). Bell furnaces with water-sealed retorts must be provided with overflow pipes from the water seals so that a sufficient flow of cool water can be used to prevent an appreciable rise in the water temperature. The atmosphere gas in contact with warm water on the inside lip of the seal will absorb water, which diffuses into the load chamber and which may cause discoloration of the work.

CONTROLLING AND TESTING FOR DECARBURIZATION

CARBON POTENTIAL VS DEW POINT

If no change in carbon content of the work is desired, it is necessary to establish a carbon potential in the protective atmosphere equivalent to that of the steel being treated. This carbon potential can be estimated accurately by measuring the dew point; a high dew point means a low carbon potential, and a low dew point a high carbon potential.

Because most heat-treating atmospheres contain hydrogen, any inward leakage of oxygen will combine with the hydrogen in a hot furnace to form water vapor and thus increase the dew point. Also, if the work being heated in such an atmosphere has a coating of rust or oxide, the hydrogen will react with the oxide to form water vapor and likewise increase the dew point.

DRYING OUT A FURNACE

One of the first problems in establishing a carbon potential in a furnace is to be able to maintain the desired dew point in the empty furnace. If the furnace is new or has been repaired and contains new brickwork, a drying-out period will be required. Usually this is accomplished by heating the furnace to the maximum temperature for which it is designed and by maintaining this temperature constantly for periods ranging from two to ten days. All the brickwork and insulation must be heated as much as possible to "steam out" the moisture contained. Sometimes this drying process is aided by applying a temporary insulating blanket to the outside of the casing of the furnace heating chamber.

Before starting to dry out a furnace, it should be tested for air leaks and atmosphere tightness. Then, during the drying process, an atmosphere gas should be introduced into the furnace to carry out the water which is steamed out of the brickwork. In the later stages of drying, the atmosphere gas should be free of CO_2 and H_2O; it will penetrate the brickwork, and by diffusion will carry out moisture which would otherwise be difficult to remove.

Once the furnace is dry, it is well to maintain the dryness by continuous operation at working temperature and with the proper atmosphere being maintained. A temporary shutdown, such as over a weekend when the temperature of the furnace is allowed to drop and the atmosphere gas is removed, may require an operating period of 24 to 48 hr to recondition the furnace to the desired dew point.

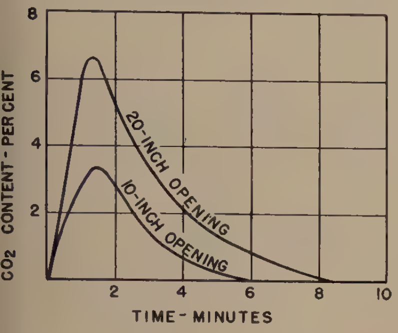


Fig. 156. CO_2 contamination caused by opening door of box-type furnace with protective atmosphere and gas-flame curtain. Samples of gas taken at hearth level in center of furnace

CARBON POTENTIAL OF GAS

Tests

(XX). Proper conditioning of a furnace to the desired carbon potential can be accurately checked by a carbon analysis of steel samples treated in the furnace. For this test, low-carbon steel shim stock, approximately 0.010 in. in thickness, makes a suitable sample. Such a sample piece will, in about one hour, establish a carbon content throughout its thickness which will be equivalent to the carbon potential of the atmosphere in which it is treated. Thus, upon taking a carbon analysis of the sample, the carbon potential of the protective atmosphere is determined.

Other methods of testing for carbon potential outlined in Parts V and VI included hardness readings by testing heat-treated parts on a hardness-testing machine or by checking with a file, measuring weight gain or loss on test specimens, and microscopic examination, using samples of the particular carbon steel to be treated in production.

OTHER FACTORS WHICH MAY AFFECT RESULTS

(A). Steel parts to be hardened should be checked for surface decarburization before treatment. If the carbon concentration is low at the surface, proper hardening may not be obtained.

(B). Ordinarily the temperature should be the lowest that will produce the proper hardness or the characteristic desired. As illustrated in Part II, the higher the temperature, the higher must be the carbon potential to prevent decarburization.

(C). Time at temperature should be as short as possible to prevent decarburization (or carburization), unless the atmosphere carbon potential is perfectly balanced to that of the steel. In the gas-carburizing process, a high carbon potential is established, of course, and time must be allowed for the carbon to penetrate the steel surface to the desired depth and concentration.

How to Take Gas Samples for Analysis

Collecting a sample of the atmosphere gas as generated is usually a simple matter. Generally, however, it is also necessary to get a sample direct from the furnace chamber for properly determining furnace conditions. For taking samples from inside a furnace chamber, the following suggestions are given:

(XXI). When a portable gas analyzer is placed in a location near the sample outlet, the gas sample can be taken directly into the burette through a rubber tube. If the gas to be sampled is not under a slight pressure, it will be necessary to purge the sample tube by pumping out the sample with an aspirator bulb.

Be sure the tubing is completely purged and no air is taken in with the sample.

When the gas sample must be taken to a laboratory-type measuring burette, a sample bottle is used. This can be a small container of glass or metal with a capacity of about 200 cc. Each end terminates with a stop cock and nipple connection. Fill the bottle with clean water, being sure to remove all air bubbles even to the tip end of the nipple.

To take a gas sample place the rubber tube, from which the sample gas is escaping, over a nipple of the bottle. Then open the stop cocks and allow the water to run out and be displaced by the gas sample. Shut off the drain cock while some water is remaining in the sample bottle to insure no infiltration of air. After shutting off the top cock and disconnecting the bottle, turn the bottle over and allow a part of the remaining water to run out and fill the cock and nipple through which the sample entered.

(XXII). To get a representative sample, the sampling point should not be too close to an atmosphere inlet. Also, the entering atmosphere must have time to adjust itself to furnace conditions.

(XXIII). A sample should not be drawn from just an opening in the furnace casing, but through a tube which is inserted through the wall of the furnace into the furnace chamber.

(XXIV). The sampling tube through the furnace wall should be small, approximately ¼ in. I.D., and preferably of quartz or ceramic material. Thus, the sample is drawn quickly from the furnace and quenched with a minimum possibility of a change in composition. If such materials are not available, usually a heat-resistant alloy tube is satisfactory. It is not advisable to use iron or copper tubing because these may cause changes in the gas sample while it is being drawn through the hot section of the tube.

(XXV). Be sure to purge the sampling tube completely before taking a sample, and make connections tight to avoid air leakage.

(XXVI). When taking samples for dew point measurements, be certain that all tubing and the instrument and its connections are at a temperature above the dew point of the gas being tested.

(*To be continued*)

HIGH LIGHTS AND SIDE LIGHTS

Computing Machine with a Memory

The electronic computer illustrated also on the Cover will be 5000 times faster than a human being in supplying the answers to complex mathematical problems encountered in engineering and science. Although officially unnamed as yet, it is presently referred to as "Omibac," an engineering abbreviation for "Ordinal Memory Inspecting Binary Automatic Calculator."

Project engineer makes adjustment on one of two "memory" cylinders which supply instructions and numbers to Omibac for solving complex mathematical problems

Omibac is a digital computer which deals directly with the digits of the original problem, as contrasted with the analog computer, which translates the problem into analagous terms such as length, speed, or voltage. It employs the binary system of counting, a simplified method which utilizes only two digits—1 and 0—rather than the 10 characters of the familiar decimal system.

Because the binary system's two digits can be made to answer to an electrical "on" or "off," the system lends itself readily to high-speed computers which make use of essentially "on-off" electronic, electric, and electromechanical tools.

The new calculator does its work by means of more than 3300 electron tubes and associated electric circuits, and two "memory" devices. It can "remember" more than 1000 separate instructions and more than 1000 numbers, producing this stored-away information when called upon to do so. The machine's memory comes from fast-spinning cylinders coated with a black magnetic material, on which its orders are recorded in the form of magnetic impressions. One cylinder contains instructions, in binary code, which determine what the machine does and when. Another contains the numbers Omibac will be called upon to use in the solution of a particular problem.

Orders coming from the instruction cylinder determine not only the selection of numbers but also whether the numbers are to be added, subtracted, multiplied, or divided. The instructions and numbers can be erased, replaced with others, or retained permanently. An important use of Omibac will be in solving either repetitive problems or those with thousands of steps. The computer will be most efficient, for instance, in working on problems that might take days or weeks merely for the programming, or setting up of the sequence by mathematicians for solution of the problem.

Once the program has been set up, instructions and numbers will be fed into the machine by suitable means such as tape, perforated by an operator at a keyboard similar to that of a standard typewriter, which translates the instructions into binary form. Tripped off by combinations of perforations in the tape, electric impulses record by magnetic means the numbers and instructions in the machine's memory.

If the problem is highly complex, the machine may operate for hours or days—entirely automatically—before producing the final result. Such problems would take months or even years for a human to solve.

Bouncing Putty Finds Therapeutic Use

When prescribed by a physician, bouncing putty can be used to exercise the muscles of the fingers, hands, and arms in certain cases of muscular disability resulting from polio, stroke, arthritis, broken bones, or other causes. This interesting material, a silicone product, has replaced the rubber ball in many hospitals and occupational-therapy schools.

Unlike actual putty, the silicone bouncing putty is not greasy; when stretched out slowly it looks and feels very much like bubble-gum or taffy; if pulled quickly it will break; when struck with a hammer it will shatter almost like glass—yet when it is rolled into a ball and dropped on the floor, it bounces back into the air with alacrity.

The material offers opportunity for considerable entertainment for the patients using it. Little statues and figures can be modeled from the material, and when placed upon the desk or table during rest periods, such figures very slowly melt down into a pool of putty.

A similar material is being used for shock-absorbing padding around the camera and other instruments packed into V-2 rockets. When these instruments strike the earth after their flight, they are protected from injury by the bouncing putty.

New Instrument for X-ray Analysis of Structure

Scientists can now explore unknown substances with x-rays and determine in a few minutes what elements the substances contain and how the atoms in them are arranged, by means of an automatic instrument recently developed.

Called an "x-ray spectrogoniometer," the instrument makes its analyses by means of x rays, an especially sensitive Geiger counter, and a system of gears machined to the accuracy of those used to guide major astronomical telescopes.

A Geiger counter is a type of tube, used widely in the atomic-energy field, which gives minute electrical signals when certain rays—x rays and cosmic rays—strike it.

A sample to be analyzed is mounted in the center of a large table. An x-ray beam is passed through it, and the Geiger counter, moved by precision gears, rotates around it slowly, measuring the intensity of x rays scattered by the sample at every angle. The manner in which a substance scatters x rays is governed by the type of atoms it contains and the way in which they are arranged with respect to each other.

Intensities of the x rays and the angles at which they are scattered are recorded automatically on a moving strip of paper in the form of a graph. The record is marked off in the degrees of a circle through which the Geiger counter moves, and the x-ray intensities are indicated by the height of the line drawn by the recorder.

The principal method of making x-ray analyses of structure in the past has involved the use of photographic film. The

Record of an unknown chemical sample is drawn automatically by the x-ray spectrogoniometer

scattered x rays were picked up on a photographic film surrounding the sample, and the angles at which they were diffracted were calculated from measurements made on the film.

The technique made possible by the new instrument is much faster and more accurate than the photographic method.

The entire unit resembles a large kneehole desk, with the revolving parts, x-ray tube, sample-holder, and Geiger counter mounted in the center of its top.

Ship's Energy Meter

How much energy a ship expends on a given trip can now be measured by the marine shaft horsepower-hour meter.

The new instrument is expected to prove valuable in keeping a continuous check on the performance of ships' power plants, enabling operators to select the most economical speeds for the plants, and indicating when the ships should be drydocked because of drag caused by fouled hulls.

The meter indicates both the power being transmitted to the propellers at any instant and the total energy expended over a period of time. The energy measurement is registered in terms of horsepower-hours and is said to be accurate to within two percent.

Heart of the device is a small, self-contained unit, mounted on the ship's propeller shaft, which measures the speed of the shaft and the amount of twisting the shaft is subjected to. The product of these two quantities, calculated automatically, gives the horsepower and, when multiplied by time, gives the total energy.

That part of the equipment which registers the information and contains the instrument's controls can be mounted anywhere aboard ship—in the engine room, at the engineer's desk, or on the bridge.

Particle Count of Air Pollution

Science has produced an instrument that counts invisible particles in the air a million billion times smaller than a grain of sand.

Developed under Project Cirrus, joint weather research program of the U. S. Army Signal Corps and the Office of Naval Research, in consultation with the G-E Research Laboratory, the device will be used to study the behavior of particles in the atmosphere, determine how they disperse, and find out how far they travel.

Such knowledge will be useful in developing atmosphere-seeding techniques for silver iodide, which in similar small-particle form causes supercooled or below-freezing moisture to turn to snow.

The device should prove useful also in air-pollution studies to trace the development and dissipation of various smokes from industrial centers and populated areas.

Particles detected are less than a millionth of an inch in diameter and have been found in concentrations as low as 1000 per cu in. and as high as 10,000,000 per cu in.

In use thus far the instrument has detected high concentrations of particles in clouds five miles high. High concentrations have been found also in areas subject to smoke pollution, especially those downwind from a city.

The new instrument consists principally of a cloud chamber, through which a beam of light is directed, an air pump which compresses and expands air three times a second in the cloud chamber, a moisture supply which introduces moisture into the chamber, and a light-sensitive photoelectric cell which watches the beam of light.

Air to be tested for appearance of particles continuously passes through the cloud chamber. The sudden expansion of this air causes condensation of moisture on any particles present, resulting in fog of various densities.

The amount of light scattering from the beam is in proportion to the number of fog drops formed, and any changes in the light scattering are detected by the electric eye and transmitted as electric impulses to a recorder, which indicates the change graphically on paper. The number of particles is then determined by calibration.

Underground Fire Traced by Mercury-vapor Detector

Progress of one of the largest man-made fires in history, burning underground 55 miles northwest of Birmingham (Ala.), is being followed by means of an electronic mercury-vapor detector.

The fire, started intentionally last March, is in the Gorgas Mine, where experiments in producing gas by igniting a coal vein underground are being conducted by the U.S. Bureau of Mines and the Southern Research Institute. At regular intervals through the vein, small capsules of mercury have been placed in the path of the blaze. The mercury-vapor

(Concluded on next page)

St. Paul's White Way

A mercury-vapor system has been installed along University Avenue in St. Paul (Minn.). One hundred seven luminaires, containing 21,000-lumen mercury lamps, are mounted in a horizontal position 31 ft 6 in. above the pavement and spaced approximately 100 ft apart in an opposite arrangement detector keeps a constant check on the gases pouring from the mine. When the fire, which may create temperatures as high as 3000 F, reaches a capsule, the mercury is vaporized, and the instrument detects the fact.

The mercury-vapor detector, which has found its widest application in the public health field, insuring the safety of persons working near mercury, makes use of the fact that ultraviolet light is scattered when it passes through an atmosphere containing mercury vapor. Gases to be tested are passed through a tube, between an ultraviolet light source and an electric eye. If the gases contain mercury vapor, the light reaching the electric eye will be lessened and the instrument reading will change.

The detector is not affected by carbon monoxide and hydrocarbons produced by the subterranean fire.

Studying 0.000002-inch Film Surfaces

Research engineers of a western petroleum company are engaged in development of new and improved lubricants and catalysts by using an electron diffraction instrument, which can "see" film surfaces as thin as two millionths of an inch.

In these two research activities it was found necessary to provide equipment and techniques to reveal quickly the crystalline surface condition of specimen material under actual operating conditions.

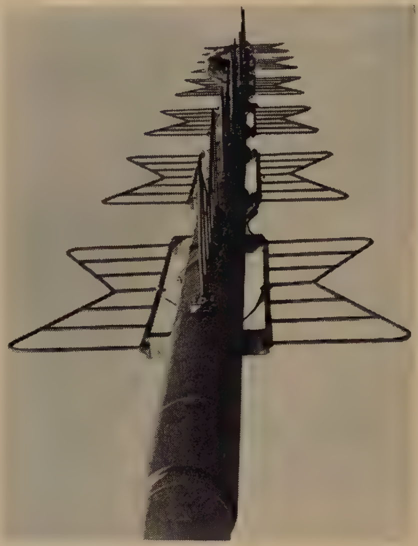
The electron diffraction instrument is the most sensitive device yet developed for observing chemical and physical changes in extremely thin films.

Before its development, the only means of studying such films was by x-ray diffraction or chemical analysis, methods which may show only one chemical composition whereas electron diffraction photographs will reveal a very thin surface layer of another material.

According to engineers the electron diffraction method permits a truer evaluation of surface-active materials, and may lead to the discovery of new lubricants or lubricant additives. An important advantage of this method is the speed with which the analysis of surfaces and thin films can be made.

Studies are being carried out on aromatic-producing catalysts, cracking catalysts, and other catalysts of present interest or possible future interest for producing better petroleum products.

Designed for a High Wind



Final tests atop the world's largest heavy-duty low-band television antenna, installed by Station KRLD-TV, Dallas (Tex.). Designed for 50-lb-per-sq-ft wind loading, corresponding to 150-mph wind velocity, the antenna weighs 10,000 lb and is 99 ft long

Vibration Tests for Strength

A device which works like a harmonica, vibrating metal strips in a path of rushing air, is now being used to test the strength of metals. In the pneumatic tester, compressed air vibrates the test strip.

The pneumatic strip tester vibrates metal in strip or sheet form at its natural frequency, until the specimen fails. The number of vibrations needed to cause failure indicates the metal's strength.

While the test is in progress, the strip intercepts a beam of light once during each vibration. Since the light beam is focused on a photoelectric cell, or electric eye, the vibrations can be counted electronically and the exact frequency can be found.

When a test strip begins to crack, it ceases to vibrate as before, and the testing device automatically stops. Engineers then multiply the frequency at which the test was run by the time needed to cause failure, to find the number of vibrations the metal strip could stand before it cracked.

Because of the high frequencies which can be produced on the pneumatic strip tester—tests are often run at 1000 vibrations per second—metal strips can be vibrated enough times in 24 hours to equal two or three weeks' testing on mechanically operated devices.

Voltage Multiplier for Small Generators

A new machine designed to increase a hundredfold the voltage produced by a small shop-size generator is now in the developmental stage.

Called the "voltage multiplier," the machine may eventually be used in conjunction with x-ray equipment and atom smashers. Initial tests show that it may provide a compact source of high voltage.

The voltage multiplier operates on the principle of the old-fashioned water wheel: While a water wheel develops power as its buckets fill with water, the new voltage multiplier builds up energy by "filling" 100 capacitors with electric charges. Connected in series, the capacitors accumulate energy by picking up their charges through a sweeping arm, with finger-tip brushes. The new machine multiplies the 1000 volts of a small generator to a total voltage of 100,000 volts.

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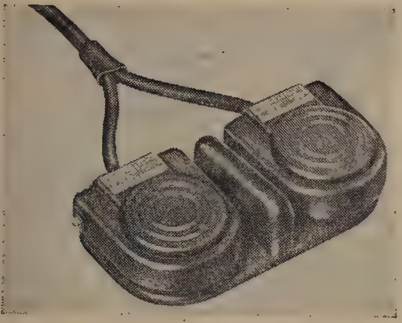
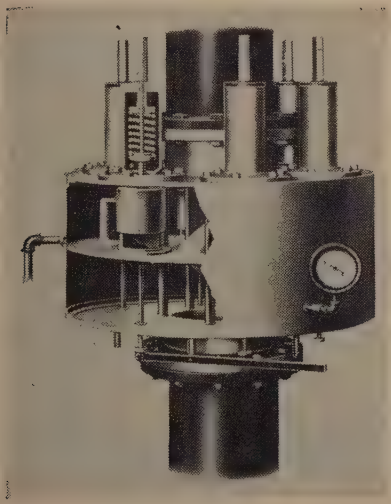
NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM



Treadle Switch

Temperature Indicators



Back-pressure Valves

Back-pressure Valves

Two new back-pressure valves: Type 135VM will maintain steam pressure at any desired point between 0 and 20 psi; Type 136VW is an atmospheric-relief valve for vacuum service. Both valves are suitable for heating systems, power plants, and process applications where close regulation of large quantities of steam is required. Wire drawing and hunting with pulsating flows are virtually eliminated by these valves because the individual valve units can be set to open in sequence. Thus, at small increments of pressure, only one valve at a time is in a throttling position. Individual and positive testing or setting of each valve unit can be done without dismantling the valve. Likewise, repairs or replacement of one unit does not prevent operation of the valve as a whole.—*Klipfel Valves, Inc., Div. Hamilton-Thomas Corp., Hamilton, Ohio.*

Treadle Switch

A new Linemaster TWIN-COMPACT foot-treadle switch for forward and reverse motor operation. It consists of a pair of tiny 6½ oz switches mounted on a cast-aluminum base. To prevent accidental simultaneous operation of both, a sturdy bridge separates them. The industry-tested switch actuating mechanism is unusually sensitive. These twin compacts are sturdily constructed of heavy-gage steel, and have a cork composition nonskid base.—*Simonds Machine Co., Inc., Southbridge, Mass.*

Temperature Indicators

High-temperature-rated pellets are now available to indicate 2100, 2200, 2300, 2400, and 2500 F. Beginning with 113 F, pellets are produced in 12½-deg steps to 400 F, in 50-deg steps from 400 to 2000 F, and in 100-deg steps from 2000 to 2500 F. The surface shown in the illustration was heated to a temperature between 2400 and 2500 F; the 2400-deg pellet has begun to melt while the 2500-deg pellet remains intact. Tempilstiks, a crayon form of temperature indicator, are available in corresponding intervals from 113 to 2000 F. Tempilaq, a paint form of indicator, comes in similar steps from 113 to only 1600 F.—*Tempil Corporation, 132 West 22nd St., New York 11, N. Y.*

Speed Changers

Gear reductions as high as 750,000 to 1 are now practical and available in a new line of miniature speed changers. These special units are made up by adding one or two additional gearing sections to the standard three-section units having ratios up to 3375 to 1. This provides several hundred ratios between 1000:1 and 750,000:1. Input speeds as high as 50,000 rpm, and output torques up to 2 lb-in. are permissible. Very high ratios in hobbed gears and zero-backlash construction can be furnished at reduced torque rating. Weights of 4- and 5-section units are approximately 6 and 7 oz.—*Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.*

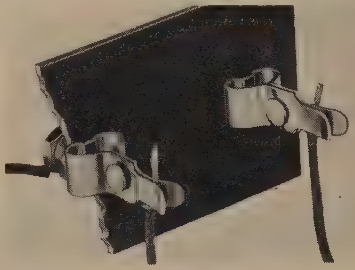
Auxiliary Motor

A new modified base-ventilated motor designed specifically for external applications such as driving power-station auxiliaries mounted out-of-doors. The motor, in ratings from 200 to 3000 hp, can be mounted on a concrete base which is raised sufficiently from the ground to allow contaminated ambient air to flow through the foundation at high velocity, as in a storm. Ventilating air enters the motor through a vertical passage in the base, and is pulled from the ambient air stream at low velocity, when almost no water or foreign matter can be carried up vertically into the motor.

After circulating through the motor, the ventilating air is exhausted from the top. Exhaust ports are protected by an overhanging metal shield and baffling. Should air enter the exhaust ports during heavy storms, adequate elimination and drainage are provided.—*Small and Medium Motor Divisions, General Electric Company, Schenectady 5, N. Y.*

Test Clip

A new test clip for speed and convenience in testing assembly-line products and experimental apparatus in laboratories. It can be permanently mounted on the panel of any test equipment or, for one-time applications, can be mounted temporarily. Because additional operations, such as opening or closing jaws, are eliminated, testing time is reduced to a minimum. Leads are simply slipped in or out of the clamp-type jaws. Spring action holds the wire firmly until the operator pulls out the lead. Tension of the spring action is adjusted by tightening the hex nut that mounts the clip to the panel, and two such nuts are included with each clip.—*Grayhill Co., 4524 West Madison St., Chicago 24, Ill.*



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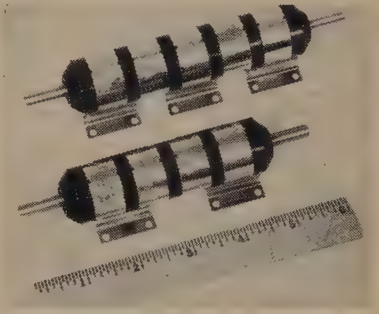
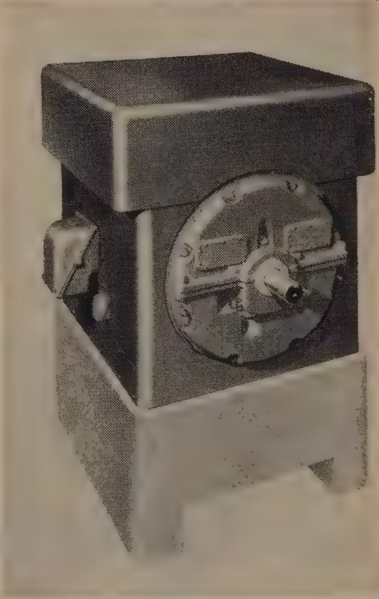


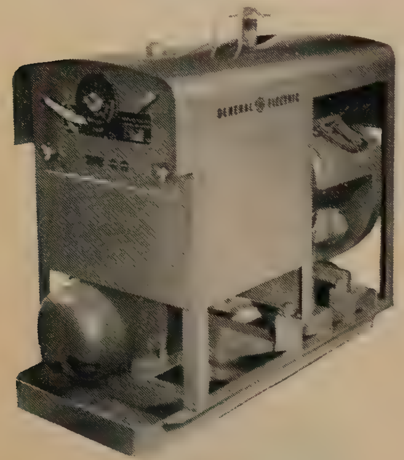
Speed Changers



Auxiliary Motor

D-c Arc Welders

A new line of WD-40 Series lightweight mobile engine-driven d-c arc welders. The general-purpose heavy-duty welder, WD-42AGW, is driven by a 31-hp Wisconsin VP-4 air-cooled engine with a magneto ignition. It weighs 1050 lb, and its rated output is 200 amp at 40 volts. Others are the WD-43AG and WD-44AG, powered by a 6-cylinder 63-hp Chrysler industrial engine. The WD-43AG, rated 300 amp at 40 volts, is frequently used in the construction industry for welding beams and girders, and for general maintenance work.



Four welders in the series are diesel driven. The WD-43ADGM and WD-43ADC have a welding range of 60 to 375 amp. In the 400-amp line are the WD-44ADGM and WD-44ADC.—*Welding Division, General Electric Company, Schenectady 5, N. Y.*

Plastic Insulated Wire

A new type of tinned-copper conductor, with insulation of $\frac{1}{32}$-in. wall of specially compounded stabilized vinyl dielectric has been approved by U-L for 105 C continuous operations. This conductor is free-stripping and permits practical applications wherein soldering operations are to be encountered. This development in the art of plastic insulation solves, on an economical basis, the insulated-wire inventory problem because consumers of hook-up and lead wire need stock only one single type of plastic insulated wire for all such practical purposes. —*William Brand & Company, 276 Fourth Ave., New York 10, N. Y.*

Carbide Hammers

Combination bolt-heading and marking hammers of solid carbide for automatic bolt-heading machines. With the new hammers manufacturers can, simultaneously with the heading operation, mark bolts, screws and rivets to indicate size or analysis of metal and, at the same time, taking advantage of the extreme hardness and wear resistance of tungsten carbide to assure clean markings over long runs. The hammers are available with either male or female markings, and in a complete range of sizes. Any pattern, numerals, combination of lines, etc., can be furnished.—*Carboloy Company, Inc., Detroit 32, Mich.*

Winding Machine

A new high-speed No. 102 coil winder has a speed of 5000 rpm, and handles coils with a high number of turns with maximum operator output. To synchronize winding time with handling time on a three-head winder, it is desirable that handling time be no greater than one-half the time required for winding one coil. The high speed of the new winder permits an operator to take care of three heads, winding coils containing up to 5000 turns and requiring 30 sec handling time, without unproductive waiting time on the part of the operator. Redesign of this machine has also provided for sealing against oil leakage.—*Universal Winding Co., Providence, R. I.*

Metal Ceramics

A new metal-ceramic material with unusual physical characteristics. Some of these characteristics are: high thermal shock resistance; high strength at elevated temperatures; good abrasion resistance; and intermediate electrical and thermal conductivity. The material is also machineable and suitable for electroplating. Possible uses include: dies for hot-forming, containers for high-temperature furnace work, jet-engine and rocket components, flux-resistant-welding and brazing fixtures, electrical contacts, and spark-plug electrodes. Sample orders for small pieces are being accepted.—*P. R. Mallory & Co., Inc., Special Metals Division, 3029 East Washington St., Indianapolis 6, Indiana.*

Sealing Compound

A new silicone dielectric compound called G-E 81083. This smooth, homogeneous mixture is designed to provide a chemically stable, waterproof, dielectric sealing compound for aircraft ignition systems and electronic equipment. The compound forms a waterproof seal and is substantially unchanged by temperatures from −70 F to 450 F. It will wet and adhere to both metallic and nonmetallic surfaces,

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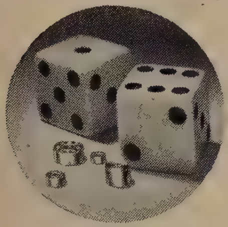

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but is noncorrosive and relatively inert chemically. As a dielectric, it prevents arcing due to moisture condensation on spark plugs, coils, etc.—*General Electric Company, Chemical Dept., Pittsfield, Mass.*

Volume Level Indicators

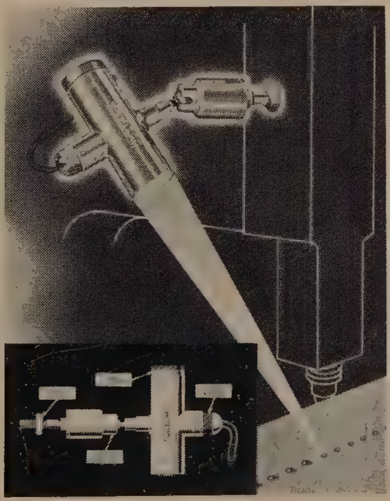
A new and completely redesigned line of volume level indicators designed to indicate audio levels in broadcasting, sound records, and allied fields where precise monitoring is important. The indicating meter is a copper-oxide-type instrument for monitoring purposes. Adjustment is such that the pointer will indicate 99 percent normal deflection at zero vu in approximately 0.3 sec. Two meter controls are provided: one a small decade with screw-driver adjustment for zero-level setting of the meter pointer; the other a constant impedance T-type network for extending the range of the instrument in steps of 2 db.—*Daven Company, 191 Central Ave., Newark 4, New Jersey.*

Copper Paste

Copper in paste form, called Cubond, provides substantial savings in assembly of parts for furnace copper-brazing. The paste offers a source of copper that can be applied with more speed and less waste than from such sources as rings, foil, slugs, and electroplate. An applicator gun is used to apply the paste as an extrusion in the form of rounds or ribbons in definite quantity, depending on the trigger setting. These guns are for pneumatic or hand use. The pastes are produced in two general types: one has a synthetic petroleum base; the other contains a base that does not change its viscosity with changes in temperature.—*Metals Refining Co., Div. of Glidden Co., 1717 Summer St., Hammond, Ind.*

Spotlight

A new spotlight for accurately locating work on blind operations. It overcomes the difficulty of positioning large assemblies on all types of equipment such as resistance welders, automatic riveters, dimpling and counter-sinking machines, punch and drill presses, etc. The spotlight is easily positioned on a ball and socket joint, and the spot of light can be adjusted to as small as ⅛ in. diam. The light is intense enough to be clearly visible under all sharp lighting conditions. The chrome-plated sturdily made unit has a special lens to permit sharp definition of the spot in a wide range of diameters.—*Sciaky Bros., Inc., 4915 West 67th St., Chicago 38, Ill.*



Cathode-ray Tube

A new 3-in. 3MP1 cathode-ray tube, originally designed for use in small industrial oscilloscopes, is expected to find numerous applications for television servicing and for testing industrial apparatus such as welders, amplifiers, and electronic timing devices. Special processing of the screen gives a brighter trace than normal tubes of the same electrical ratings. It is an electrostatic focus and deflection type with a bulb diameter of 3⅛ in. and useful screen diameter of 2¾ in. It is equipped with a small-shell duodecal base which has been set as the standard base on all television tube types.

Maximum ratings include an anode No. 1 d-c voltage of 1000 volts and an anode No. 2 d-c voltage of 2500 volts. The maximum negative-bias value is 200 volts d-c and the positive-bias value 2 volts d-c. Other max values are: Grid No. 1 circuit resistance, 1.5 megohms; resistance in any deflecting electrode circuit, 5 megohms.—*Tube Divisions, General Electric Company, Schenectady 5, N. Y.*

X-ray Tube

A new miniature x-ray tube, the Mini-X 045A, for use in dental radiography. This tiny tube measures 2¼ in. in length and 1⅛ in. in diameter. An important feature of the tube is that it has a stabilized amount of radiation output and its radiation is highly concentrated for producing higher contrast and greater definition in the x-ray picture. X-ray units built around this tube will be about one-third the size of normal equipment, will permit greater portability, require less space, and will be one-third less in weight than conventional units.—*Amperex Electronic Corp., 25 Washington St., Brooklyn 1, New York.*

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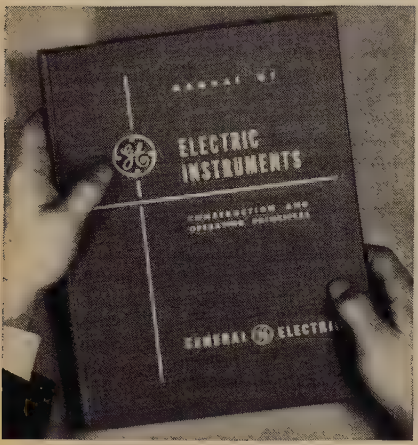

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TRADE LITERATURE

Beryllium-copper Products—Two publications containing data for specifying beryllium-copper wrought products and a brief analysis of available alloys, conditions, and tempers. Tables give mill sizes and properties. Four pages each. "How to Order Beryllium-copper Strip": Bulletin 12. "How to Order Beryllium-copper Rod, Bar, and Wire": Bulletin 13.—*Beryllium Corp., Reading, Pa.*

Cables—A booklet directed to utilities and their engineers, containing detailed technical information on low-pressure, medium-pressure, and high-pressure gas-filled cables. Some of the specific subjects covered are operation, application, and performance. Twelve pages. Titled "Gas-filled Cables."—*General Electric Company, Construction Materials Dept., Bridgeport 2, Conn.*

Dispensers and Flow Gage—The improved line of Rato-Chlor chlorine dispensers is presented. Several of the self-contained cabinet-type units are illustrated, and the operation and design features are described. Twelve pages. Catalog 61. Another bulletin describes a completely redesigned Magna-Sight flow gage, a simple low-cost flow-rate indicator for coolants, lubricants, opaque liquids, slurries, and other fluids. Four pages. Catalog 96.—*Fischer & Porter Co., Hatboro, Pa.*

Electrical Tape—A cleverly designed folder to aid in the proper selection of the right Permacel electrical tape for particular requirements. Recommended uses for each tape is given, and the most recent price list included. Four pages, plus six single-page inserts. Titled "Permacel Electrical Tapes." —*Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill.*

Instruments—"Advanced Instrumentation for Steam-operated Generating Stations" titles a booklet in which the "continuous balance" principle is described and the constructional and operating features of the various ElectroniK instruments are illustrated, including strip-chart and circular-chart potentiometers; indicating, recording, and signalling potentiometers; and precision scanning indicators. Thirty-two pages. Bulletin 90-1.—*Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Wayne and Windrim Aves., Philadelphia 44, Pa.*

Lathe Operation—After a brief history of lathe development, there follows 10 chapters covering various phases of lathe operation with detailed instructions for proper usage. Numerous sketches and illustrations materially aid in supplementing the descriptive text. One hundred twenty-eight pages. Titled "How to Run a Lathe." —*South Bend Lathe Works, South Bend 22, Indiana.*

Locknuts and Washers—Contains detailed dimensions of a new line of bearing-positioning locknuts and lockwashers designed for effectively locking the various makes of ball and roller bearings in correct position on shafts. Four pages. Folder No. 2348.—*Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.*

Mounting Bases—A neatly presented description of air-damped mounting bases for control of shock and vibration in airborne equipment. In addition to photographs and drawings, tables of load ratings are included. Eight pages. Catalog 502.—*Barry Corp., 179 Sidney St., Cambridge, Mass.*

Radiographic Materials—A catalog of materials for industrial radiography describing films for use with x-ray equipment of varying kilovoltage and with specimens of varying thickness and density. A handy chart enables prompt selection of best suited materials for particular needs. Sixteen pages. Titled "Materials and Accessories for Industrial Radiography."—*X-Ray Division, Eastman Kodak Co., 343 State St., Rochester 4, New York.*

Safety Switches—Contains latest information about high-capacity interrupter Type A safety switches. A detailed explanation of the arc-quenching action of a new grid-pin design which breaks up the arc and thus interrupts heavy loads quickly and cleanly is illustrated by several schematic drawings. Other features described include center-front operation, front fusing, and roller-cam action. Six pages. Folder TEC-10.—*The Trumbull Electric Manufacturing Co., Plainville, Conn.*

Solder Pre-Forms—Arranged to explain the what, how, and when of the uses of pre-formed solder shapes, this bulletin is terse and informative, with a special illustrated chart showing applications in diverse fields and instances. It is Universal punched for easy insertion in loose-leaf binders. Four pages. Titled "How to Speed Up Soldered Assemblies with Solder Pre-Forms."—*Soldering Specialties, Summit, New Jersey.*

Step Voltage Regulators—Detailed description of the design, control, operation, and application, together with the customary outlines and dimensions for step voltage regulators. Sixteen pages. GEC-530.—*General Electric Co., Apparatus Dept., Schenectady 5, New York.*

Vacuum Calculator—A slide-rule device that easily and quickly determines needed pump capacity to evacuate a given volume to a specified vacuum in a given time, as well as the time required to evacuate a given volume to a specified vacuum with an existing vacuum pump. Also includes basic conversion tables for vacuum operations together with other useful data. Titled "Stokes Vacuum Calculator." Price 50c.—*F. J. Stokes Machine Co., 5900 Tabor Road, Philadelphia 20, Pa.*

Wired Television—Numerous application sketches effectively show how objects, operations, or conditions can be observed continuously by Utiliscope equipment—wired television. Listed are its many advantages and possibilities in the fields of industry, research, commerce, education, and science. Sixteen pages. Bulletin 1025.—*Diamond Power Specialty Corp., Lancaster, Ohio.*

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery: none sent on approval.)

THE WORLD AS I SEE IT (New Abridged Edition) Albert Einstein—Philosophical Library, Inc., New York. 1949. xiii+112 pp. $2.75.

Albert Einstein is now seventy years old. He first came to fame in 1905 when he published three brief but remarkable papers on (1) the special theory of relativity; (2) the Brownian movements; and (3) photoelectric stopping potentials. Each of these three papers presented new and far-reaching generalizations of immense importance. The revolutionary changes in science, and the whole world of thought that have stemmed from Einstein's work, mark him as one of the greatest men now living.

Those who have worked with him say that, despite his immense contributions to physics, his greatest qualities lie in the field of character and morals. For that reason, this little book is a most important and indeed fascinating volume. A few quotations from it show the elevated thought, great range of ideas, and yet naive approach of this great man to world problems:

> "The passion for scientific inquiry is not to be crushed by any burdens. The man who is possessed with it perishes sooner than it does."
>
> "The only rational way of educating is to be an example."
>
> "A man's ethical behavior should be based effectually on sympathy, education, and social ties."
>
> "Nothing is more destructive of respect for the government than passing laws which cannot be enforced."
>
> "I desire to work with all my might for the establishment of an international arbitrating and regulative authority superior to the state."
>
> "I, too, am in favor of abolishing large cities."

P. L. ALGER

THE CHARACTERISTICS OF ELECTRICAL DISCHARGES IN MAGNETIC FIELDS
Edited by A. Guthrie and R. K. Wakerling—McGraw-Hill Book Co., Inc., New York. 1949. xviii + 376 pp. $3.50.

This book is essentially a collection of technical reports of the atomic energy program, which under normal publishing conditions would probably have appeared as a series of scientific papers. Much of the book is concerned with a low-pressure "arc" in new and rather specialized surroundings. This discharge consists of a beam of electrons accelerated from a filament and collimated by a slot as it enters a graphite box and is subjected to a longitudinal magnetic field. The plasma formed by the beam is studied under various conditions of pressure, magnetic field, beam current, etc. The conclusions of some derivations are only partially verified by experiment.

An introductory chapter serves to orient the reader and to provide a loose organization of the rest of the material presented. Chapter 2 presents the characteristics of probes used to explore plasma, together with theoretical considerations of the phenomena involved, special attention being given to the effect of a magnetic field. A new theory is developed that gives order-of-magnitude agreement with experiment for electron and positive ion currents to a probe on a magnetic field. Chapters 3 and 4 present brief theoretical considerations of the sheath region about electrodes, and of the minimum pressure for a stable arc in a magnetic field. The characteristics of arcs near the threshold pressure for a stable arc with magnetic field are presented in Chapter 5 for A, He, and SF_6. Two mechanical diagrams are difficult to understand because of unconventional presentation.

The apparatus and experimental results of a study of the cross-sections for ionization of UCl_4 and UF_6 by electron collisions up to 500 ev are discussed in Chapter 6; the results for UF_6 are inconclusive. A study of the ionization and dissociation products and their appearance potentials of UCl_4 and UF_6 under electron impact is presented in Chapter 7.

In Chapter 8 is a brief consideration of the rate of ion production by an electron beam. Chapter 9 presents a diffusion theory of the arc plasma in a magnetic field together with a large amount of new experimental data on the phenomena associated with this type of discharge. Special attention is given to the effect of potential distribution on ion losses from the plasma, and considerable space is devoted to the presentation of the characteristics of the oscillations and electrical noise (called by the technical slang term "hash") present in the discharge. The statement is made that a great amount of work has resulted in no real understanding of the nature of hash. However, no reference is made to OSRD reports and papers on this subject published since the war.

The use of discharges as sources of electrons is considered in Chapter 10, and the theory and operation of the Philips ionization gage type of discharge is given in Chapter 11. The index is adequate, but references throughout the book are sketchy.

J. D. COBINE

THE MATHEMATICS OF CIRCUIT ANALYSIS
Ernst A. Guillemin—John Wiley & Sons, Inc., New York. 1949. xiv + 590 pp. $7.50.

This volume is a mathematical supplement to the anonymous series of undergraduate texts written by the staff of the Electrical Engineering Department at Massachusetts Institute of Technology. The first half of the book deals with mathematical topics needed in the analysis of electric circuits; the second half emphasizes those employed in synthesis. It has been planned also to be a source book for advanced students and practicing engineers, besides serving as an undergraduate text.

The chapters in the first half cover determinants, matrices, linear transformations, quadratic forms, and vector analysis. Curiously enough, their arrangement and development is such that they all could just as well have been grouped under the title "Tensor Algebra," had not the author been still scared of tensors. He prefers to employ the archaic terminology and notation of invariant theory still fashionable in conservative circles, although he himself has some misgivings about such usage. The view is taken in the book, in connection with the definition of the metric tensor, that matrix

(Continued on next page)

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BOOK REVIEWS (Continued)

algebra is an invaluable aid to clear comprehension of the tensor method. It is regrettable that the author has not followed the point of view recommended. His awkward symbolism might have been greatly improved even by such a minor concession as the use of upper and lower indices.

The pioneering work done by the author and his pupils in the field of network synthesis has enabled him to select, out of the large realm of the theory of functions of a complex variable, more diverse topics useful to the engineer than is customary in similar texts. The chapter on Fourier series and integrals brings to the level of the engineer much material found only in Courant-Hilbert.

A striking characteristic of this mathematical text on electric circuits is the complete absence of circuits. The author will receive many compliments and just as many rebukes for such a radical departure in teaching applied mathematics.

Gabriel Kron

Maintenance Manual of Electronic Control

Edited by Robert E. Miller—McGraw-Hill Book Co., Inc., New York. 1949. xi + 304 pp. $4.50.

Here is a maintenance manual which has been written in a down-to-earth fashion so that the average layman can read it and understand it with little difficulty. It should be a valuable asset to those people who have installation or maintenance problems as a part of their daily routine.

The first chapter presents the basic principles of electronic control by describing a number of the simpler control circuits. Here the author gives the basic thinking back of circuit design and demonstrates various control functions by example.

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The second chapter is devoted to general instructions regarding installation and maintenance. This includes the use of various industrial symbols, diagrams, meters, tube-testing equipment, and other valuable servicing aids.

A full chapter is devoted to the use of the cathode-ray oscillograph, which permits the service man, in a few seconds, to see the voltages that actually exist in any part of the circuit, and which gives him a better picture with which to analyze the problem at hand. There is no question but that this is a very valuable story and warrants careful study.

The remaining chapters take up in detail the installation problems associated directly with particular types of control. Special trouble-shooting instructions are given and a chart covering both a suggested inspection schedule and trouble-shooting analysis appears for each type. Special wiring precautions are given, describing the type of pickup trouble that may be encountered and how it can be avoided by proper use of shielded cable and grounding.

Numerous other common problems are treated. In the ignitron-rectifier chapter, special instructions regarding the care of the ignitrons and the associated firing equipment have been adequately covered and should provide most of the answers required to meet questions arising in the field.

Although some of the equipment treated is not of the most recent design, nevertheless the principles laid down for shooting trouble and maintaining this equipment are basically sound and represent a normal procedure that could be followed in servicing any type of control. The book should serve as a background which, when coupled with specific instructions regarding a particular control, should place the service man in an excellent position to meet the problem with confidence. In addition, its recommended inspection schedules can be made the starting point for the most useful type of maintenance—preventive maintenance.

Ben Cooper

Industrial Electronics

Harold W. Ranney—Delmar Publishers, Inc., Albany (N. Y.). 1949. vii + 213 pp. Paper covers, plastic bound, $3.25; cloth-bound, $4.00.

This book forms a part of the Electrical Radio Series produced under the supervision of the New York State Education Department for use in vocational and industrial training. Mr. Ranney is supervisor of Industrial Teachers Training and has taken a great personal interest in establishing and developing the industrial electronic work in the vocational and industrial schools of the state.

During the war a serious need arose for better training in industrial electronics for electricians, technicians, service men, and vocational instructors and was met with the assistance of the General Electric Company's Industrial Control Division Electronic engineers as instructors. Their lecture notes and laboratory material have been proved by a number of years of actual classroom use and form the basis for this text. Mr. Ranney has done an excellent job of consolidating and editing the material and has produced a well written clear and simple explanation, well arranged and profusely illustrated.

The book is divided into two parts; the first half is explanatory and the second covers a series of laboratory experiments based on the text. Adequate but not excessive space is given to the fundamental tube characteristics. The basic control circuits for each type tube follow the tube description. In addition, typical examples are described of such widely used applications as resistance welding, time-delay relays, and photoelectric register control.

A very valuable feature is the emphasis placed on the use of the cathode-ray oscilloscope for electronic servicing. In the text section the shapes of typical wave forms are inserted frequently and in the experimental section numerous cross-hatched circles are provided for sketches by the students of the wave shapes observed.

An appendix including definitions, ASA graphical symbols, glossary of industrial electronic equipment, and tables of rectifier circuit data complete this well-rounded volume.

W. D. Cockrell

Elements of Diesel Engineering (2nd Edition)

Orville L. Adams—Norman W. Henley Publishing Co., New York. 1949. xii + 367 pp. $5.00.

The book, though elementary, gives a clear and straightforward presentation of the subject. The first three chapters cover very well the basic fundamentals of definitions, mathematics, and cycles. Later chapters amply set forth the elements of fuel injection, combustion and heat, rating and testing, indicator diagrams, fuel and lubricating oils and fuel properties, and engine performance. A chapter on air intake and supercharging is included; however, this deals mainly, and very well, from the engine standpoint and does not attempt to go into the elements of superchargers themselves.

Students, young engineers, and others seeking fundamentals, will find the information they seek in logical order, well presented and illustrated. There is a wealth of drawings, curves, and tables which will answer many questions about engines. Basic formulas are given, but derivations are omitted. There are some excellent examples in the text and appendix; and the questions and answers at the end of each chapter will serve as a check to the student as to his retention and understanding of the main points of the chapter.

The author prepared the original book on the basis of his own experience over a period of years, and the text and data are brought up to date from later experience by this second edition.

Engineers will find the book useful and a credit to their libraries.

R. R. Blunt

Transformation Calculus and Electrical Transients

Stanford Goldman—Prentice-Hall, Inc., New York. 1949. xiv + 439 pp. $8.35.

A brief glance through this book will make you want to look twice, for it is crammed full of useful mathematics for the engineer.

While primarily for the electrical engineer, it is certainly not limited to this field, for transients are important in many other types of systems, too. The transformation of co-ordinates from one plane to another is especially applicable to fluid flow and electrical field problems.

The author assumes that the reader has had some calculus and has at least been exposed to complex quantities and differential equations. He begins laying a firm foundation in the first two chapters by re-

(Continued on next left-hand page)

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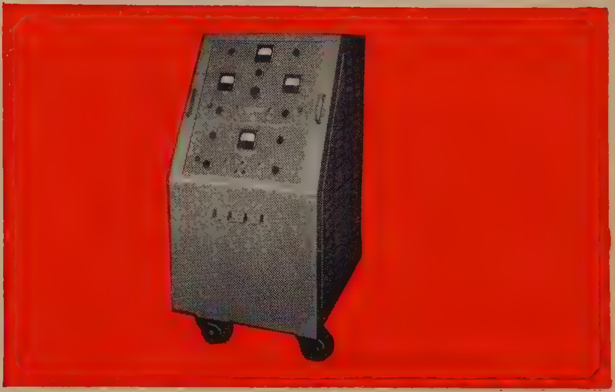

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viewing determinants, basic differential equations, and fundamental properties of electric circuits.

The solution of transients by Laplace transforms is then given, which includes an explanation of Heaviside's expansion theorem. The chapters that follow explain the theory of function of the complex variable, loci of complex functions, the inversion theorem, gamma and error functions, Bessel functions, partial differential equations, solutions in series, and additional applications. Many of the problems are treated in a manner similar to those treated in Heaviside's operational calculus, but with a transformation approach instead of the operational. Hence the name "transformation calculus."

The author has succeeded in producing an excellent book that should prove quite interesting and useful to all engineers.

H. C. Ward, Jr.

Two Lectures: I. The Present Situation in the Theory of Elementary Particles. II. Electron Theory of Superconductivity

W. Heisenberg—Cambridge University Press, London and New York. 1949. 52 pp. $1.00.

These two lectures were delivered at the Cavendish Laboratory at Cambridge in December 1947. They are aimed primarily at specialists in the two fields covered, and presume a reasonable familiarity with the recent literature in quantum electrodynamics and meson theory, and in the electron theory of metals.

The two subjects are presented so as to contrast two different sorts of difficulties which face the theoretical physicist. In the theory of elementary particles the problem is to find a set of postulates and concepts which will lead not only to a correct description of phenomena but also to a logically consistent mathematical theory. In the theory of superconductivity the fundamental postulates and concepts are well established, and the problem is to find approximations and simplifications in the quantum mechanics of the many-body problem which make it amenable to calculation while retaining the essentials necessary to the explanation of superconductivity.

Both lectures cover controversial territory and will be seriously questioned in detail by other workers in the field. However, Professor Heisenberg's indication of the general direction in which solutions should be sought will undoubtedly be agreed to by the majority of physicists.

Harvey Brooks

Extrapolation, Interpolation, and Smoothing of Stationary Time Series

Norbert Wiener—Published jointly by Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York. 1949. 163 pp. $4.00.

If a review of this book were limited to one word, then in this reviewer's opinion the word is "prediction." The fundamental problems of the book are that of optimum (subject to useful conditions) prediction and smoothing of continuous or discrete time series, whether the time series has its origin in the general field of statistics or communication engineering—for example, whether the data originate in discrete stock-market statistics or from continuous-wave or pulse fire-control radar signals.

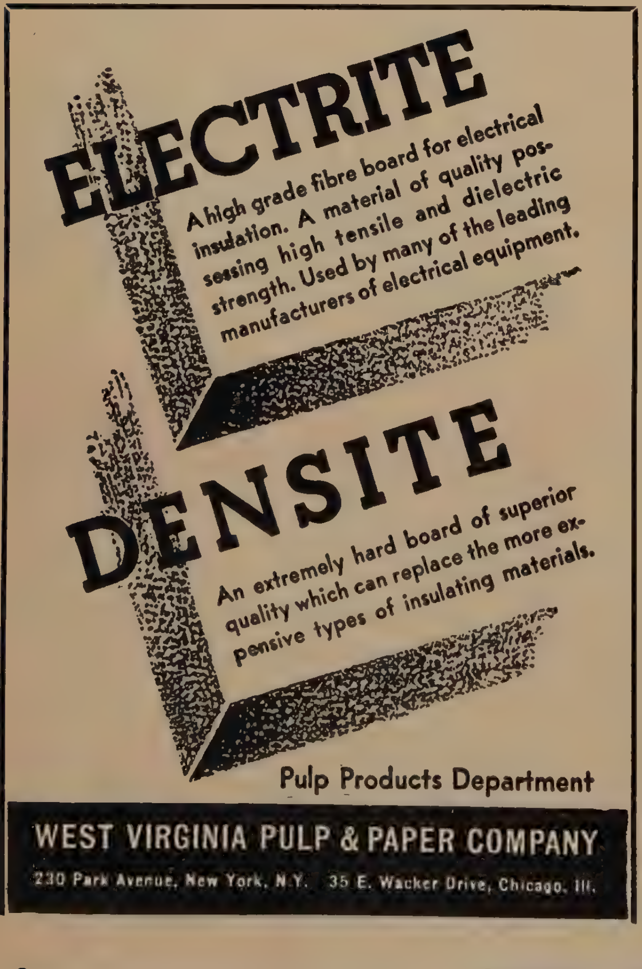
This is one of the outstanding scientific contributions of World War II, whether it is viewed as research work in a field of applied mathematics, a basic source for additional research, a reference text, or a collection of tools bridging the gap between statistical and communication science. The contents of the book are original, having been published first as a classified report to section D_2, National Defense Research Committee. This classical work has been the starting point, and in many cases the basis, of numerous researches in fire-control during World War II.

As a reference this book is largely self-contained; Chapter I includes a résumé of needed fundamental mathematical notions. Various autocorrelation functions are the basic statistical functions employed. The minimization of the mean square error over the time interval concerned implies the solution of integral equations of the Wiener-Hopf type. Among other mathematical tools employed are contour integration, orthogonal expansions, Fourier Transforms, and Wiener's Generalized Harmonic Analysis. The coördination of the statistical and communication fields can only be suggested by the example given in the first paragraph of this review.

Chapters II and III are devoted to filtering and predicting of single time series, and Chapter IV is a generalization of the theory to multiple time series. The last chapter is concerned with general concepts of time-series differentiation, interpolation, and extrapolation.

The book should be in the library of all professional statisticians and all technically inclined communication engineers.

E. G. Keller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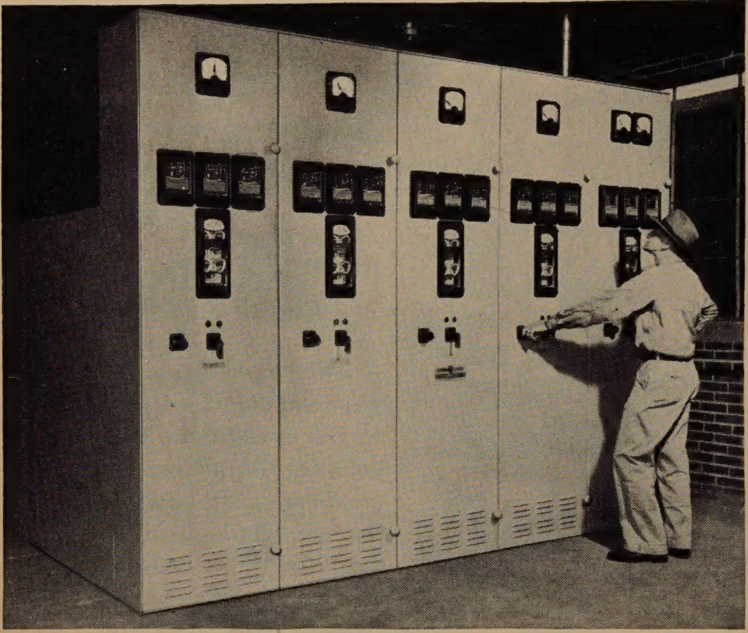
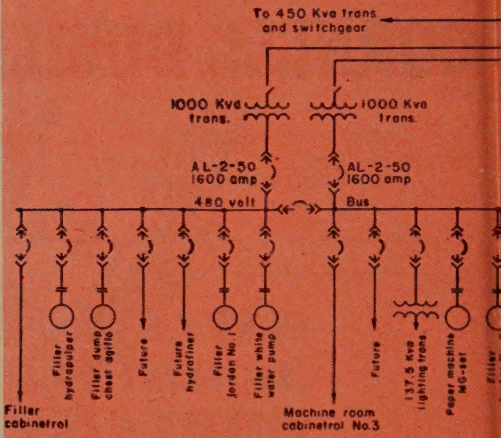


General Electric 5-kv Type MI-6 metal-clad switchgear consisting of one incoming-line breaker and four feeder breakers to handle 4160 volts at Fairfield Paper and Container Co. Magne-blast air circuit breakers are rated 1200 amperes, 100,000 kva interrupting rating. Note neat appearance of metal-clad unit. It's space saving too, and the metal-clad construction offers operating safety to personnel. Units like this are easily installed and can be added to with a minimum of bother and expense. Instruments and relays are co-ordinated for positive protection of circuits.

One-line Diagram
Fairfield Paper and
Container Company



G-E Cabinetrol units provide centralized control for the liner stock system. Unit controls motors, valves, agitators, etc. Ammeters record load carried by hydrapulper and hydrofiner. Four other Cabinetrol units are used throughout the mill.

The Fairfield installation is a complete General Electric project—one source of responsibility plus the very best in co-ordinated planning, engineering, manufacturing, and servicing facilities to give maximum savings and efficiency to the customer.

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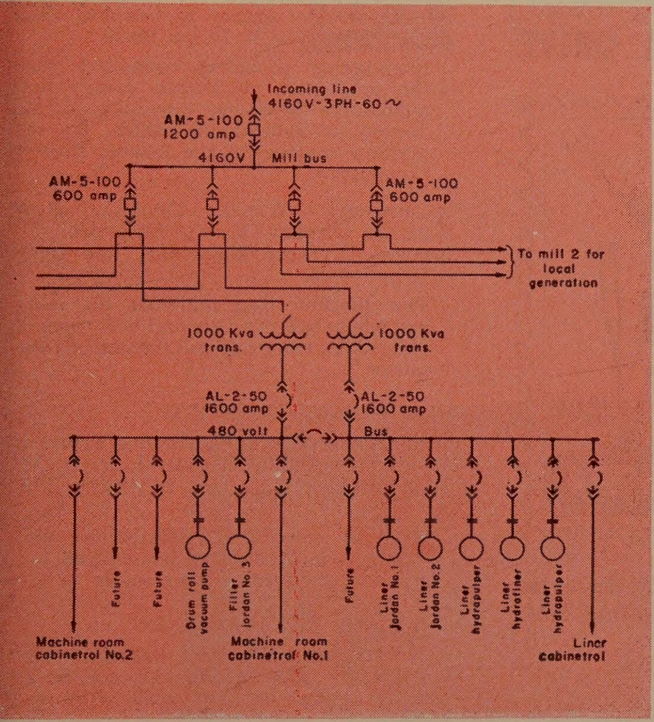

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

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Condensation on Prefabricated Walls, by E. R. Queer and E. R. McLaughlin. *Heat. Piping & Air Cond.*, Dec. 1949; v. 21, pp. 99-104.

Results of tests on dwelling walls of different materials and under various operating conditions.

Panel Heat Ties in With Air-conditioning System. *Power*, Dec. 1949; v. 93, pp. 1112-1115.

New plant has a split air-conditioning system that uses ceiling-mounted radiant heating, also deepwell water for all cooling-coil service.

Storing Solar Heat in Chemicals—A Report on the Dover House, by Maria Telkes and Eleanor Raymond. *Heat & Vent.*, Nov. 1949; v. 46, pp. 80-86.

A house completed in Dover, Mass., and occupied since December, 1948, uses the heat of fusion of low-cost chemical compounds for storing solar heat.

ALLOYS

Determination of Arsenic in Lead and Tin Alloys, by Louis Silverman. *Iron Age*, Dec. 15, 1949; v. 164, pp. 96-98.

Description of a rapid colorimetric method.

Magnetic Ferrites—Core Materials for High Frequencies, by C. L. Snyder and others. *Elec. Mfg.*, Dec. 1949; v. 44, pp. 86-91.

Consisting only of metallic oxides, Ferramics have high-volume resistivity and high permeability, but low losses, making for reduction in size and weight in h-f magnetic circuitry.

Magnetic Ferrites for High-frequency Uses, by Frank G. Brockman. *Elec. Engng.*, Dec. 1949; v. 68, pp. 1077-1080.

Describes the development, the characteristics, and applications of these materials.

CAST IRON

A Practical Evaluation of Ductile Cast Iron, by T. E. Eagan and J. D. James. *Iron Age*, Dec. 8, 1949; v. 164, pp. 75-79.

Based on a series of tests involving full-size castings.

Some Engineering Aspects of Nodular Cast Iron, by C. R. Austin. *Iron Age*, Dec. 1, 1949; v. 164, pp. 79-85.

Extensive data on microstructures and physical properties, and results of dynamometer tests of nodular-iron brake drums are given.

ELECTRIC WELDING

Influence of Consumption Rates on Flash Welding, by W. N. Platte. *Weld. Jour.*, Dec. 1949; v. 28, pp. 584s-598s.

Effect of material thickness, consumption rate, voltage, current, and temperature were investigated. Optimum flashing schedules have been established.

Standardized Equipment for Resistance Welding, by Wallace A. Stanley. *Weld. Engr.*, Dec. 1949; v. 34, pp. 34-40, 42.

The chief types of welding machines and power-supply systems.

FURNACES, INDUSTRIAL

Mullite and Zircon Furnace Tubes for High-temperature and High-vacuum Systems; New Method for Measuring Pressure, by Earl A. Gulbransen and Kenneth F. Andrew. *Ind. & Engng. Chem.*, Dec. 1949; v. 41, pp. 2762-2767.

The design, construction, and testing of refractory porcelain furnace units which are of double-walled construction and which can be sealed direct to a Pyrex glass vacuum system.

EASTER SEAL DRIVE

National Society for Crippled Children and Adults, 11 S. LaSalle St., Chicago 3, Ill.

IRON AND STEEL

Steel Analysis Time Cut by Radiofrequency Heating, by W. K. Aites. *Steel*, Dec. 12, 1949; v. 125, pp. 92-93, 112.

How, operating at temperatures exceeding 3000 F, high-frequency induction heating is used successfully in carbon and sulphur analysis, reducing carbon determination time from 10 to 2½ minutes.

LIQUIDS

Convection Currents in Porous Media. II: Observation of Conditions at Onset, by H. L. Morrison and others. *Jour. App. Physics*, Nov. 1949; v. 20, pp. 1027-1029.

Small-scale experiments have been carried out for determining the minimum vertical thermal gradient which is required to cause convection in liquids entrapped in porous media.

MACHINE DESIGN

Design Considerations for Manufacturing Economy, by Roger W. Bolz. *Mech. Engng.*, Dec. 1949; v. 71, pp. 1004-1010.

Careful designing for production can achieve a variety of substantial economies in manufacture, a factor all too often overlooked.

PLASTICS

Electrical Requirements of Plastics Molding Machines Are Tough! by Mark Morgan. *Elec. Mfg.*, Dec. 1949; v. 44, pp. 102-106, 188, 190.

Drive equipment for molding machines.

Use of Plastics in Aircraft. *Tech. Data Digest*, Jan. 1, 1950; v. 15, pp. 15-23.

A group of three separate articles.

RADIOACTIVITY

Learning to Live With Atomic Radiation—A Challenge to Engineering Profession, by Arthur E. Gorman. *Civil Engng.*, Dec. 1949; v. 19, pp. 28-29.

Engineering problems connected with the production of atomic energy and radioactive products, especially in the disposal of radioactive wastes. By the sanitary engineer of the Atomic Energy Commission.

Radioactive Waste Disposal—How Will It Affect Man's Economy? by Kenneth G. Scott. *Nucleonics*, Jan. 1950; v. 6, pp. 18-25.

The question that underlies the more immediate one of where and how users of radioactive materials will dispose of their wastes.

STANDARDS, ELECTRIC

Constructive Standardization Typified by Transformer Program—I, by H. M. Jalonack. *Elec. Wld.*, Dec. 3, 1949; v. 132, pp. 87-90.

Drafting minimized, fabrication and shipment facilitated. Order evolved out of distribution-transformer chaos.

TRACERS, RADIOACTIVE

Radiochromium Plating for Friction Studies, by John T. Burwell and S. F. Murray. *Nucleonics*, Jan. 1950; v. 6, pp. 34-37.

Describes the application of radiochromium to piston rings as another instance of the successful use of radioisotopes to study the phenomena of friction.

VIBRATIONS

Vibration of Multifrequency Systems During Acceleration Through Critical Speeds, by G. D. McCann, Jr. and R. R. Bennett. *Jour. App. Mech.*, Dec. 1949; v. 16, pp. 375-382.

Presents generalized solutions for the response of a linear two-degree-of-freedom system excited by a single constant-magnitude sinusoidal force whose frequency varies uniformly with time.

X-RAYS

X-ray Camera for Obtaining Powder Pictures at High Pressures, by A. W. Lawson and N. A. Riley. *Rev. of Sci. Instr.*, Nov. 1949; v. 22, pp. 763-765.

Two methods are described of obtaining x-ray powder-diffraction pictures of materials subjected to high hydrostatic pressures. Both techniques have been successfully employed to identify simple high-pressure structures at pressures ranging up to 15,000 atmos.